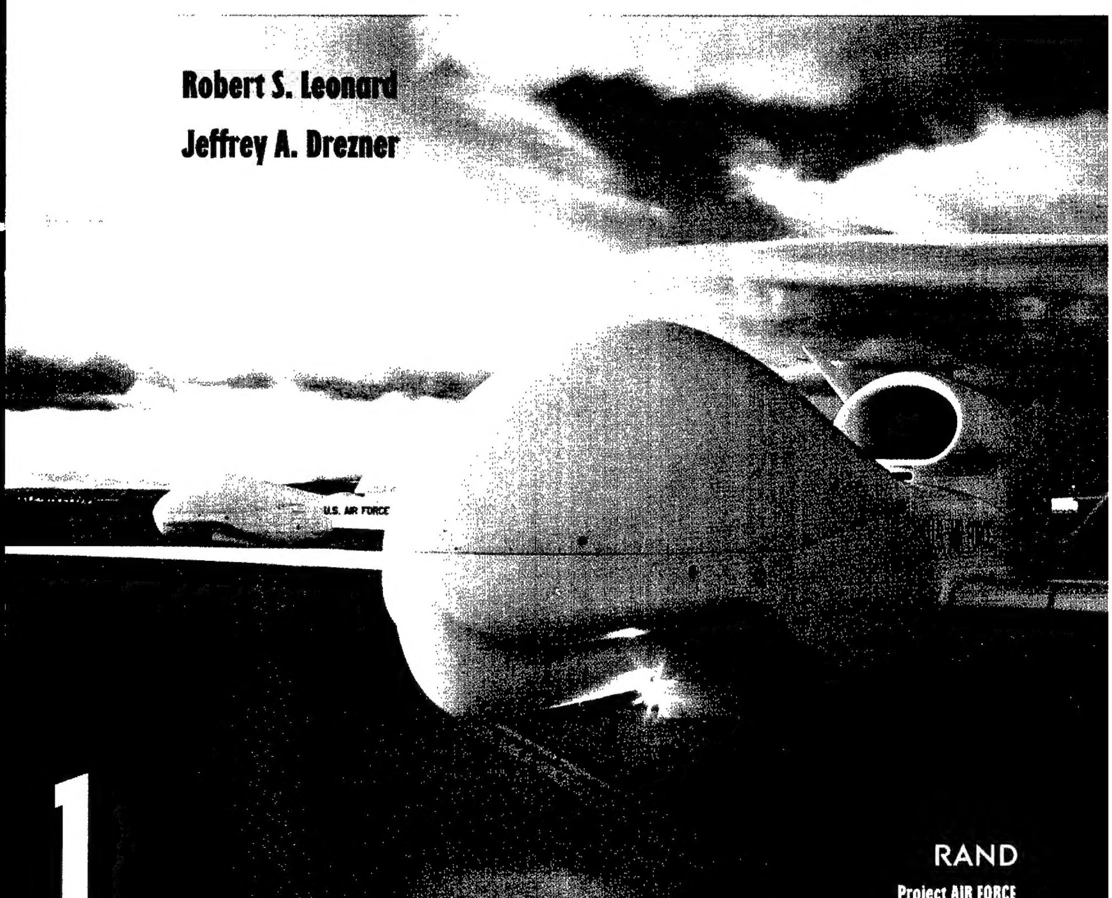
INNOVATIVE DEVELOPMENT

Global Hawk and DarkStar

HAE UAV ACTD Program Description and Comparative Analysis

Robert S. Leonard
Jeffrey A. Drezner



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RAND
Project AIR FORCE

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Robert S. Leonard

Jeffrey A. Drezner

Prepared for the United States Air Force

RAND

Project AIR FORCE

The research reported here was sponsored by the United States Air Force under Contract F49642-01-C-0003. Further information may be obtained from the Strategic Planning Division, Directorate of Plans, Hq USAF.

ISBN: 0-8330-3112-0

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Cover design by Barbara Angell Caslon

Published 2002 by RAND
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
201 North Craig Street, Suite 102, Pittsburgh, PA 15213-1516
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PREFACE

The High-Altitude Endurance Unmanned Aerial Vehicle (HAE UAV) Advanced Concept Technology Demonstration (ACTD) program incorporated a number of innovative elements into its development strategy. As a condition of conducting this ACTD, Congress required that an independent third party study its implementation. RAND was chosen for this role and has been following the HAE UAV ACTD program since its inception.[1]

The joint program, which was undertaken from early 1994 to late 2000, was conducted under the direction of the Defense Advanced Research Projects Agency (DARPA) and the Defense Airborne Reconnaissance Office (DARO) in its early years and by the United States Air Force in its later years. The initial research was sponsored by DARPA; the current research is sponsored by the Air Force.

The core objective of the research was twofold: to understand how the innovative development strategy used in the HAE UAV ACTD program affected program execution and outcomes, and to draw lessons from this experience that would be applicable to the wider acquisition community. Four reports were written at the conclusion of the ACTD. This report describes the activity content of the HAE UAV ACTD program and compares its outcomes to what is tradi-

[1]See Geoffrey Sommer, Giles K. Smith, John L. Birkler, and James R. Chiesa, *The Global Hawk Unmanned Aerial Vehicle Acquisition Process: A Summary of Phase I Experience*, MR-809-DARPA, Santa Monica: RAND, 1997; and Jeffrey A. Drezner, Geoffrey Sommer, and Robert S. Leonard, *Innovative Management in the DARPA High Altitude Endurance Unmanned Aerial Vehicle Program: Phase II Experience*, MR-1054-DARPA, Santa Monica: RAND, 1999.

tionally accomplished in major defense system developments. It is one of three supporting documents resulting from the current research effort; the other two documents track transition management–related issues and analyze the flight test program. The fourth document is an executive summary that covers all aspects of the research.

This research was sponsored by the Global Hawk System Program Office (GHSPO), part of the Aeronautical Systems Center/Reconnaissance Air Vehicle (ASC/RAV) directorate of Air Force Materiel Command (AFMC). It was conducted within RAND's Project AIR FORCE.

Reports in this series are:

MR-1473-AF, *Innovative Development: Global Hawk and DarkStar—Their Advanced Concept Technology Demonstrator Program Experience, Executive Summary*, Jeffrey A. Drezner, Robert S. Leonard

MR-1474-AF, *Innovative Development: Global Hawk and DarkStar—HAE UAV ACTD Program Description and Comparative Analysis*, Robert S. Leonard, Jeffrey A. Drezner

MR-1475-AF, I*nnovative Development: Global Hawk and DarkStar—Flight Test in the HAE UAV ACTD Program*, Jeffrey A. Drezner, Robert S. Leonard

MR-1476-AF, *Innovative Development: Global Hawk and DarkStar—Transitions Within and Out of the HAE UAV ACTD Program*, Jeffrey A. Drezner, Robert S. Leonard

PROJECT AIR FORCE

Project AIR FORCE, a division of RAND, is the Air Force federally funded research and development center (FFRDC) for studies and analyses. It provides the Air Force with independent analyses of policy alternatives affecting the development, employment, combat readiness, and support of current and future aerospace forces. Research is performed in four programs: Aerospace Force Development; Manpower, Personnel, and Training; Resource Management; and Strategy and Doctrine.

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SUMMARY

The United States has seen a three-decade-long history of poor outcomes in unmanned aerial vehicle (UAV) development efforts. Technical problems have led to cost growth and schedule slip as well as to disappointing operational results. Costs have tended to escalate so much during development that the resulting systems have cost more than users have been willing to pay, precipitating program cancellation in almost every case. This history prompted the unique developmental approach adopted at the beginning of the High-Altitude Endurance Unmanned Aerial Vehicle (HAE UAV) program.

There has also been a long history of efforts made to improve the efficiency and effectiveness of acquisition policy, processes, and management for all system types. Capturing the experience from ongoing or recently completed efforts employing nonstandard or innovative acquisition strategies can facilitate such improvements. This research contributes to that effort.

THE GLOBAL HAWK ADVANCED CONCEPT TECHNOLOGY DEMONSTRATION WAS A SUCCESS

At the most aggregate level, Advanced Concept Technology Demonstration (ACTD) programs are intended to provide a means for the rapid, cost-effective demonstration of new capabilities and systems for the military services. If the ACTD is successful in creating a demonstrator that can provide the desired capability and if the demonstration of that capability results in a positive military utility assessment (MUA), the work accomplished during the ACTD should accelerate the introduction of the new capability into the operational

forces. Most program participants believe that this objective was achieved with the Global Hawk system. Most also believe, however, that this goal would not have been attained with the DarkStar system had it been allowed to complete the ACTD program.

The success of the Global Hawk program is extraordinary given the circumstances under which it came to be. The fundamental development of the basic system made use of a completely new and untested program management construct and was implemented by a defense agency that was not in the business of developing sophisticated military systems. The Defense Advanced Research Projects Agency (DARPA), the DoD agency charged with technology development, managed the successful basic development and proved the flightworthiness of a new system concept for which the Air Force initially had no stated requirement, budget, or interest. Initial engineering flights of the Global Hawk were so successful and compelling that the Air Force adopted the basic system concept and is now scheduled to complete engineering development and introduce the system into its operational inventory.

The ACTD program demonstrated an HAE UAV that is affordable and can provide a continuous, all-weather, day/night, wide-area surveillance capability in support of military operations. The performance of Global Hawk will be close to its stated goals. By contrast, DarkStar's basic design concept was unable to demonstrate either affordability or military utility and was eventually canceled. These mixed results are acceptable within the ACTD construct.

PROGRAM DESCRIPTION

The HAE UAV ACTD program included two air vehicles: a conventional configuration and a low-observable (LO) configuration. A common ground segment (CGS) was added not long after program initiation. The ACTD program was structured into three phases. Phase I was a design competition for the conventional Tier II+ system. Phase II included the development and test of both the Tier II+ (Global Hawk) and the LO Tier III– (DarkStar). Phase III involved the demonstration and evaluation (D&E) activity leading to an MUA.

The use of Other Transaction Authority (OTA) and the program's designation as an ACTD shaped the planning and execution of HAE

UAV system development from the program's inception in April 1994 through the conclusion of the ACTD in 2001. The OTA provides a blanket waiver of normal acquisition rules and regulations and allows considerable management responsibility to devolve to the contractor. An ACTD has a streamlined oversight process, bounds cost and schedule, and includes early user participation. These elements of the program's management approach greatly affected program execution, particularly with regard to how the program's activity content changed over time.

Tier III– (DarkStar) system development efforts began in June 1994 when the Lockheed Advanced Development Company[2] signed an Agreement to build the first two air vehicles and their associated payloads, ground segments, and support items. This effort was expected to last no more than 21 months but was still not complete when concluded at the end of 1998, some 54 months after it began. Additional air vehicles and sensor suites were placed on contract beginning in November 1996. No completion date was specified. The DarkStar program was canceled in January 1999, before it had completed all that was originally called for in its Phase II engineering development activity.

For the Tier II+ system, the six-month Phase I in late 1994 to early 1995 funded five contractor teams in concept exploration/concept development efforts. For Phase II, Teledyne Ryan Aeronautical was selected to perform the basic system design as well as to build the first two air vehicles and associated payloads, ground segments, and support items. This phase began in April 1995 and lasted the better part of four years—much longer than the planned 27 months. In August 1997, Global Hawk Phase IIB was initiated with the agreement to build the next three air vehicles. An additional ground segment and sensor suites were also called for. Air vehicle manufacture extended through the end of 1999, while sensor suite work lasted through mid-2000. Global Hawk Phase III—which included D&E flight activity, additional engineering test flights, the building of a development test model (or iron bird), and an assortment of additional nonrecurring engineering development tasks—was initiated in December 1999, with activity extending through February 2001. The

[2]Now known as the Lockheed Martin Skunk Works (LMSW).

heart of the Phase III effort—the D&E exercises—took place from June 1999 through May 2000.

Significant post-ACTD development efforts in the Global Hawk program were contracted for in early and mid-2000—prior to the completion of the ACTD and still under the OTA. Phase IIC calls for the sixth and seventh air vehicles and associated sensor suites to be built. The Australian deployment effort took the system to Australia in April to May 2001 for a series of demonstration flights. Pre–engineering and manufacturing development (pre-EMD) transition activities called for further system development that will continue into 2002 and possibly beyond. The planned development efforts of Spirals 1 and 2 through 2007, which are not authorized for execution under the OTA, are expected to require a small fraction of the resources typically expended in EMD.[3] Early production models at the rate of two per year are planned to be built concurrently with Spiral 1 and 2 development activities.

THE ACTD's ACTIVITIES CHANGED RADICALLY

The fixed funding and schedule duration of the ACTD substantially constrained its activity content. The total development effort for both system concepts and for the CGS envisioned to support those concepts was subject to a $912 million budget and to a fixed ACTD conclusion date of December 1999. In the sense of what was envisioned at the beginning of the program compared to what occurred, activity content was greatly changed, while both the cost and schedule of the total effort grew only slightly.

What occurred in effect was a substantial reduction in hardware built and flight activity conducted during the ACTD to offset the much larger-than-anticipated nonrecurring engineering costs required to accomplish basic system development. In both UAV development efforts, the inherently uncertain and risky design, build, and basic testing of the first two aircraft ended up consuming a much larger

[3]Global Hawk post-ACTD development activities are planned in two iterations. Spiral 1 builds on the ACTD configuration; Spiral 2 is planned to be fully operational requirements document (ORD) compliant. The Air Force uses the term *spiral development* to describe this approach; hence the term *spiral* to define a preplanned block upgrade.

portion of the allotted budget and calendar time than had been called for in the initial ACTD plan. To stay within the ACTD's constraints, follow-on development activities and operational demonstrations were greatly curtailed. As a result, not all operational capabilities that the system might be capable of were demonstrated. This dramatic change in the activity content of the ACTD is almost unprecedented in acquisition. Yet despite these outcomes, Global Hawk was given a positive MUA and will enter an abbreviated EMD employing a spiral development process.[4]

In the Tier II+ (Global Hawk) ACTD program, it appears that had all the aircraft, sensor suites, and ground segments originally envisioned been built and had all the flight activity originally planned actually occurred, the ACTD program's cost would have grown by somewhere between 100 percent and 150 percent. To avoid any actual cost overrun, both the DARPA and Air Force program offices radically changed what was to be accomplished within the ACTD, placing their focus on achieving the objectives of the acquisition strategy rather than on blindly following the original ACTD program plan. A favorable MUA was the ultimate goal of the ACTD, and the program attained this goal while keeping actual program costs below those in the original plan.

THE UNIT FLYAWAY PRICE REQUIREMENT

The program's single requirement—that is, the $10 million Unit Flyaway Price (UFP) levied on the air vehicle segments of the DarkStar and Global Hawk systems—was unattainable and ultimately abandoned. The reasons the program failed to meet its sole requirement were threefold: (1) little or no analytical basis for the support of the UFP; (2) rationalization of the UFP through highly optimistic and essentially unrealistic assumptions; and (3) unwillingness on the part of government program management to mandate the cost control philosophy defined at the program's inception.

[4]Spiral development is defined as a cyclical, iterative build/test/fix/test/deploy process that yields continuous improvements in the system's configuration. Each configuration spiral draws on the experience and lessons of previous configurations.

The acquisition strategy called for the contractor to create the initial design and to control the configuration throughout the ACTD as required to meet the UFP. The former occurred, but the latter was not followed as had been intended. When it became clear that the UFP could not be attained without seriously degrading the performance of the system and when the contractor suggested doing just that, the DARPA-led program office would not allow it. Although DARPA was willing to back off on many of the system's desired capabilities, its unwillingness to trade off major functionality suggests that the single-UFP requirement was never strictly implemented.

The military utility demonstrated by the system later in the ACTD suggests that the retaining of all major functions desired, regardless of their impact on the UFP, was not required for a positive MUA. The very capability that the contractor wanted to remove from the system early on in the program—the electro-optical/infrared (EO/IR) sensor—was not available during the entire MUA, yet the system succeeded nonetheless. Omitting the EO/IR sensor from the system's configuration would certainly have reduced the UFP, but we now know that this major degradation would not have been enough to meet the UFP.

The UFP constraint shaped the system in both positive and negative ways. Its invocation successfully kept additional requirements from being imposed on the program. It could be held over the contractor as paramount and credibly referred to as potentially causing program cancellation if not met. This instilled a cost consciousness at the contractor that almost certainly would not have otherwise prevailed.

However, the continuous pressure on the contractor to control costs produced some negative results as well. The UFP forced design compromises that actually increased costs in the long run; government program engineers believe that total life-cycle cost will increase as a result of the UFP. It also created the potential for nonoptimal allocation of airborne and ground-based capabilities and inhibited systemwide cost control in the long run by discouraging investment in more costly basic system design solutions that would more than pay for themselves later, when the system incurs operating and support costs.

GLOBAL HAWK ACTD DEVELOPMENT WAS A BARGAIN

The development of Global Hawk and DarkStar did not involve simply building a glorified model airplane or drone, as some who view UAVs as "low tech" compared to manned aircraft might imagine. To the contrary, the Global Hawk and DarkStar programs are in many respects more complex and challenging than similar manned aircraft development efforts.

The best comparative description of what occurred in the HAE UAV ACTD program is that the effort was something more than a demonstration/validation (dem/val) but less than an EMD program. We view the ACTD as containing a prototype or dem/val-type phase, plus selected portions of a typical EMD program, plus the rough equivalent of initial operational test and evaluation (IOT&E). For Global Hawk at least, the ACTD resulted in an iteratively refined system with relatively mature technology and operational concepts.

Because of the unusual content of the ACTD, we break the development activity for the two air vehicle systems into two segments. This approach facilitates its comparison to other systems. The first segment is the early portion embodied in the ACTD's Phase II, which involved the design, build, and test of the first two air vehicles. The second segment encompasses all developmental phases that followed: Phase IIB and Phase III within the ACTD; the Phase IIC and pre-EMD activities bridging the ACTD to the Major Defense Acquisition Program (MDAP); and the two spiral EMD phases proposed within the MDAP. Comparative analyses of the ACTD's Phase II can be applied to both the Global Hawk and DarkStar programs. Comparative analyses of the remaining developmental phases in aggregate apply only to the Global Hawk program. Analysis of DarkStar beyond Phase II is not warranted because its Phase IIB, the building of follow-on aircraft, was not completed.

The total cost to the government of DarkStar Phase II lay halfway between the costs of the two programs to which it can best be compared: the Have Blue program, which created a technology demonstrator of arguably less capability than DarkStar, and the Tacit Blue program, which was described by the Air Force as one of the most successful technology demonstration programs in Air Force history and proved more capable than DarkStar. We believe that the final

cost of DarkStar Phase II was roughly what one should have expected given what was accomplished and the historical experience of similar programs.

The cost of Global Hawk Phase II was about the same as the two programs to which it can best be compared: the YF-16 and YF-17 or Lightweight Fighter (LWF) prototype programs. In these two programs, as in Global Hawk, the primary challenge lay in integrating existing technologies into a new capability. Given that the LWF prototype is viewed as one of the most successful prototype programs in Air Force history, the value of Global Hawk Phase II compares favorably, particularly when we consider that all three systems led new capabilities to be introduced into the operational forces.

The six sequential (with some overlap) development efforts beyond Phase II are in aggregate considered to be the Global Hawk program's "equivalent EMD." Global Hawk's equivalent EMD is expected to cost between $0.6 billion and $1.6 billion, with a likely value of $1.1 billion in FY 2001 dollars. This estimate compares quite favorably to the EMD expenditures for three comparative systems: the F-117A, F-16A/B, and F/A-18A/B, which cost between slightly less than $2.2 billion to more than $4.8 billion, adjusted to FY 2001 dollars. These comparisons suggest that in the case of Global Hawk, the ACTD approach to early development activities, followed by a spiral development strategy in completing the system's initial development, will lead to substantial cost savings for the fully developed system.

ACKNOWLEDGMENTS

This research would not have been possible without the cooperation of officials associated with the program in the U.S. Air Force, the Office of the Secretary of Defense, DARPA, and industry. Special thanks are due to government program office personnel and to the contractors who provided information and spent considerable time discussing the HAE UAV program.

Thoughtful reviews by Frank Fernandez and Giles Smith, and the comments of Geoffrey Sommer and Lieutenant Colonel Pat Bolibrzuch, were instrumental in ensuring the accuracy and coherence of this work. We would also like to thank Natalie Crawford and Timothy Bonds for providing their time and resources to ensure that this research would be held to the highest standards in compliance with the tenets of RAND.

Any errors are the sole responsibility of the authors.

ACRONYMS

ABIT	Airborne Information Transfer
ACAT	Acquisition Category
ACCM	Advanced Cooperative Collection Management
ACN	Airborne Communications Node
ACTD	Advanced Concept Technology Demonstration
AESA	Advanced Electronically Scanned Array
AFFTC	Air Force Flight Test Center
AFMC	Air Force Materiel Command
AFOTEC	Air Force Operational Test and Evaluation Center
AIP	ASARS Improvement Program
AITP	Airborne Interferometric SAR Program
AMST	Advanced Medium Short Takeoff and Landing Transport
ARPA	Advanced Research Projects Agency
ASARS	Advanced Synthetic Aperture Radar System
ASC	Aeronautical Systems Center
ASC/RAV	Aeronautical Systems Center/Reconnaissance Air Vehicle

ATACCS	Airborne Targeting and Cross-Cueing System
ATC	Air traffic control
BES	Budget estimate submission
BIA	Bomb Impact Assessment
BMDO	Ballistic Missile Defense Organization
BPI	Boost-Phase Intercept
BY	Base year
CGS	Common ground segment
CICA	Competition in Contracting Act
CIGSS	Common Imagery Ground/Surface System
CLIN	Contract Line Item Number
COMSEC	Communications Security
COMSAT	Communications satellite
COTS	Commercial off-the shelf (equipment)
CPAF	Cost plus award fee
CPFF	Cost plus fixed fee
CPIF	Cost plus incentive fee
CY	Calendar year
D&E	Demonstration and evaluation
DARO	Defense Airborne Reconnaissance Office
DARPA	Defense Advanced Research Projects Agency
DDL	Direct Downlink
Dem/val	Demonstration and validation
DFAR	Defense Federal Acquisition Regulation

DSB	Defense Science Board
DTM	Development Test Model
DUSD(A&T)	Deputy Under Secretary of Defense for Acquisition and Technology
EAS	Extended Air Surveillance
EMD	Engineering and manufacturing development
EO	Electro-optical
EO/IR	Electro-optical/infrared
EVMS	Earned-Value Management System
FAR	Federal Acquisition Regulation
FOPEN	Foliage Penetration
FSD	Full-scale development
FY	Fiscal year
FYDP	Future Years Defense Plan
G&A	General and administrative
GAO	U.S. General Accounting Office
GFE	Government-furnished equipment
GHSPO	Global Hawk System Program Office
GMTI	Ground Moving Target Indicator
HAE UAV	High-Altitude Endurance Unmanned Aerial Vehicle
HISAR	Hughes Integrated SAR
IFF	Identification friend or foe
IIU	Integrated Mission Management Computer Interface Unit
ILS	Integrated logistics support

IMMC	Integrated Mission Management Computer
INT	Intelligence
IOT&E	Initial operational test and evaluation
IPPD	Integrated Product and Process Development
IPT	Integrated Product Team
IRT	Independent Review Team
ISR	Intelligence, surveillance, and reconnaissance
ISS	Integrated sensor suite
JASSM	Joint Air-to-Surface Standoff Missile
JAST	Joint Advanced Strike Technology
JROC	Joint Requirements Oversight Council
JSIPS	Joint Service Imagery Processing System
LCRS	Launch, control, and recovery station
LL	Long lead
LMSW	Lockheed Martin Skunk Works
LO	Low observable
LRE	Launch and recovery element
LRIP	Low-rate initial production
LRP	Low-rate production
LWF	Lightweight Fighter
MARS	Multisensor Agile Reconnaissance System
MCE	Mission control element
MDAP	Major Defense Acquisition Program
MIS	Management Information System

MNS	Mission need statement
MOU	Memorandum of understanding
MS	Milestone
MSI/HSI	Multispectral Imagery/Hyperspectral Imagery
MTI	Moving Target Indicator
MUA	Military utility assessment
NASA	National Aeronautical and Space Administration
NBC	Nuclear, Biological, and Chemical
NRE	Nonrecurring engineering
NTE	Not to exceed
ODC	Other direct costs
OIPT	Oversight Integrated Product Team
ORD	Operational requirements document
OSD	Office of the Secretary of Defense
OT	Other Transactions
OTA	Other Transaction Authority
PASA	Passive Air Surveillance Augmentation
PDCU	Power Distribution Control Unit
PDM	Program decision memorandum
PDS	Processing and display system
PO	Program office
POL	Petroleum, oil, and lubricants
RAV	Reconnaissance Air Vehicle
RayES	Raytheon E-Systems

RCS	Radar cross section
RDT&E	Research, development, test, and evaluation
RSTA	Reconnaissance, Surveillance, and Target Acquisition
RTIP	Radar Technology Insertion Program
SAR	Synthetic aperture radar
SATCOM	Satellite communications
SBU	Strategic business unit
SIGINT	Signals Intelligence
SIL	System integration lab
SOW	Statement of work
SVI	Safety verification issue
TBD	To be determined
TCS	Tactical Control System
TDD	Task description document
TES	Test and Evaluation Squadron
TY	Then year
UAV	Unmanned aerial vehicle
UFP	Unit Flyaway Price
URE	Unintentional Radiated Emissions
USD(A&T)	Under Secretary of Defense for Acquisition and Technology
VCJCS	Vice Chairman of the Joint Chiefs of Staff
VSTOL	Vertical/short takeoff and landing
Y2K	Year 2000

Chapter One

INTRODUCTION

In April 1994, the Defense Advanced Research Projects Agency (DARPA)[1], in conjunction with the Defense Airborne Reconnaissance Office (DARO), began the High-Altitude Endurance Unmanned Aerial Vehicle (HAE UAV) program. The objective of this program was to develop and demonstrate HAE UAV systems that were capable of affordable, continuous, all-weather, wide-area surveillance in support of military operations. These systems were intended to provide intelligence, surveillance, and reconnaissance (ISR) information to the warfighter. They responded to the recommendations of the Defense Science Board and to operational needs stated by DARO on behalf of military service users.

UAV and tactical surveillance/reconnaissance programs have a history of failure—specifically, inadequate integration of sensor, platform, and ground elements—together with unit costs far exceeding what operators have been willing to pay. All these factors have contributed to a sense of frustration and to a realization that the DoD needed to explore ways to simplify and improve the acquisition process. To overcome these historical problems, DARPA, with congressional support, adopted an innovative acquisition strategy that differed from normal DoD acquisition procedures in several important ways.

[1]DARPA was known as the Advanced Research Projects Agency (ARPA) at the time of the program's initiation. Inasmuch as the agency was subsequently renamed DARPA, we refer to it as such throughout this report.

These innovations are embodied in seven specific elements of the strategy: Advanced Concept Technology Demonstration (ACTD) designation; use of Section 845/804 Other Transaction Authority (OTA); use of Integrated Product and Process Development (IPPD) and a management structure based on Integrated Product Teams (IPTs); contractor initial design and continuing configuration control; a small joint program office; user participation through early operational demonstrations; and a single requirement—Unit Flyaway Price (UFP)—with all other performance characteristics stated as goals.

The HAE UAV ACTD program consisted of two complementary system development efforts: the conventionally configured Tier II+ Global Hawk and the Tier III– DarkStar, which incorporates low-observable (LO) technology into the design of the air vehicle. The program also included a common ground segment (CGS) consisting of a launch and recovery element (LRE) and a mission control element (MCE).[2] The LRE was to provide launch and recovery for both air vehicles. The MCE was to control both air vehicles and their sensors while in the mission area and to receive, process, and disseminate the imagery collected.

The HAE UAV ACTD program was an acquisition strategy unlike traditional prototype, technology demonstration, demonstration/validation (dem/val), and full-scale development/engineering and manufacturing development (FSD/EMD)[3] programs. Because the ACTD strategy included a different set of activities than those found in the traditional acquisition process, identifying exactly what was done during the ACTD is required. This report does so and defines the term *activity content* as the activities within a specified portion of a program or the ACTD in aggregate. Defining the activity content of the ACTD's phases is useful for understanding how far along in the development process the system matured during each phase of the ACTD. Determining the activity content of the ACTD as a whole

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[2]The CGS is now known simply as the ground segment. We use the term *CGS* when referring to it in this report because it was intended to be common throughout most of the ACTD.

[3]The term *EMD* is used throughout this report both for EMD programs of the past 15 years and for the FSD programs that preceded them.

provides a foundation on which to plan what activities are required in post-ACTD acquisition activity.

RAND's ROLE

RAND has analyzed the execution of the HAE UAV ACTD program's innovative acquisition strategy since the program's inception in 1994. Previous reports documented the effects of this innovative acquisition strategy on Phase I and earlier portions of Phase II of the ACTD program.[4]

This report is one of three supporting documents resulting from the current research effort. It describes the HAE UAV ACTD program and its activity content and compares the program's actual outcomes to what was planned and to what is traditionally accomplished in major defense system developments. The other two supporting reports track transition management issues and document the flight test program. While all three documents touch on most if not all of the seven innovations of the strategy, each has specific areas of emphasis.

This report focuses on five of the seven elements of the acquisition strategy. It explores how the ACTD designation, combined with the program's OTA status and the early operational demonstration phase, shaped the program. It contains an in-depth analysis of what happened with the single requirement, the UFP, along with the government's willingness to give contractors design control and continuing configuration control to the extent required to meet the UFP. The remaining two specific elements of the acquisition strategy—the IPPD process/IPT management structure and the small joint program office—are not addressed in this report.

A fourth document, published separately, summarizes and synthesizes the results of the three more detailed reports and draws con-

[4]See Geoffrey Sommer, Giles K. Smith, John L. Birkler, and James R. Chiesa, *The Global Hawk Unmanned Aerial Vehicle Acquisition Process: A Summary of Phase I Experience*, MR-809-DARPA, Santa Monica: RAND, 1997; and Jeffrey A. Drezner, Geoffrey Sommer, and Robert S. Leonard, *Innovative Management in the DARPA High Altitude Endurance Unmanned Aerial Vehicle Program: Phase II Experience*, MR-1054-DARPA, Santa Monica: RAND, 1999.

clusions regarding the advantages and disadvantages of the innovative acquisition strategy. The summary document also provides suggestions on ways to improve the strategy for future implementation.

OBJECTIVES

The process of improving acquisition management methods, policy, and supporting analyses requires the accumulation of experience from ongoing or recently completed projects, especially those involving unusual system concepts or innovative acquisition strategies. The objectives of this research were twofold: to understand how the innovative acquisition strategy used in the HAE UAV ACTD program affected program execution and outcomes, and to identify lessons that might be applied to a wider variety of future programs, thus improving DoD acquisition strategies.

RESEARCH APPROACH

This multiyear research effort tracked and documented the execution of the HAE UAV ACTD program through the completion of the ACTD and into its transition to a Major Defense Acquisition Program (MDAP). The overall project was organized into three tasks.

Task 1: HAE UAV Program Tracking

The primary research task was to track and document the experience of both the program office and contractors as the HAE UAV ACTD program proceeded. This task involved periodic discussions with both the program office and contractors for the purpose of gaining an understanding of the program's current status, its key events and milestones, and how the innovative elements of the acquisition strategy were implemented. This task also involved a thorough review of program documentation, including solicitations, proposals, Agreements, memoranda, and program review briefings. Through discussions and reviews of documentation, we were able to assess whether the acquisition strategy had the expected effect as well as to identify issues arising in the course of program execution that either affected or were affected by the acquisition strategy.

Task 2: Comparisons to Other Programs

In this portion of the research, we collected and analyzed historical cost, schedule, performance, and flight test data from comparable past programs. Relatively little historical data at a detailed level has been preserved on past UAV programs. Past UAV development efforts tended to be canceled prior to completion, highly classified, or relatively simple systems not appropriate for comparison to HAE UAVs. These circumstances made past UAV programs a poor basis for comparison to the HAE UAV ACTD. Therefore, we assembled data on program outcomes from broader databases of historical experience to assess HAE UAV ACTD program outcomes in a historical context. We examined other programs to provide a perspective for the strategy employed in the HAE UAV ACTD program.

Task 3: Analysis and Lessons Learned

In this task, we drew together the information collected under Tasks 1 and 2. We assessed the relative success of the ACTD in three ways: Did the program perform all the activities that were envisioned at its inception? Regardless of the activities performed, did the acquisition strategy meet its specified objectives? And, finally, how do the accomplishments of the program compare with other programs using a traditional acquisition approach? Together, these results yielded an understanding of the strengths and weaknesses of the overall HAE UAV ACTD acquisition strategy. We then interpreted the results in terms of lessons that might be applied to future programs.

This report analyzes the HAE UAV program through the completion of the ACTD. It emphasizes how the innovative acquisition process affected what was done, how fast it was done, and at what cost it was done.

Chapter Two thus describes how the ACTD process differs from traditional developmental acquisition processes; the specific application of the ACTD process in the HAE UAV program; the original HAE UAV ACTD program plan and how it evolved; what was accomplished in the ACTD by its completion; and how well each program phase went in comparison to its original plan. Chapter Three then outlines the importance placed on the UFP; how the term was defined; how its estimates evolved over the course of the program;

and why the cost control strategy embodied in the UFP ultimately failed. Chapter Four addresses the technological challenges inherent in the Global Hawk and DarkStar development efforts along with those of a number of historical programs appropriate for comparison. In light of this perspective and along with the costs of the programs, we illustrate the value the government attained for its investment in the HAE UAV endeavor both in the ACTD and as predicted through the completion of Global Hawk development. Finally, in Chapter Five, we present our conclusions.

The four appendices provide details of cost, schedule, and activity content for the HAE UAV programs as understood in August 2000.

- In Appendix A, we determine which activities (Contract Line Item Numbers, or CLINs) belong in each phase of each program and give the time line for each activity.
- In Appendix B, we give a CLIN-by-CLIN accounting of cost, schedule, and activity content growth by phase using the original plan as a baseline. This is a detailed accounting of the brief discussion in Chapter Two.
- In Appendix C, we compare the details of the program's execution using original program plans as a baseline to gain a sense of how realistic those plans were.
- Finally, in Appendix D, we ignore activity content and simply compare the original ACTD cost and schedule plans to the reality of what occurred. We also give a brief view of the financial outcomes for the program's contractors.

The basic data used in this report to describe program cost and schedule are derived from the Agreements and amendments (and attachments) to those Agreements between the government and the contractors.

Chapter Two

PROGRAM DESCRIPTION: THE PLAN AND WHAT ACTUALLY HAPPENED

The acquisition strategy employed through the first seven years of the Global Hawk program, as well as through the entire four-and-one-half-year DarkStar program, differed radically from that normally used in the development of sophisticated systems. This chapter thus begins with an explanation of the circumstances leading to the ACTD program and with a discussion of the implications of the program's origins. This is followed by an explanation of how the original plans in both programs differed from the traditional acquisition process. The details of each HAE UAV program plan are then laid out, and the evolution of these plans is described. This is followed by a critique of how well the programs fared in comparison to their original plans.

PROGRAM CONTEXT

The two HAE UAV programs stem from the Long-Endurance Reconnaissance, Surveillance, and Target Acquisition (RSTA) Capability mission need statement (MNS) endorsed by the Joint Requirements Oversight Council (JROC) in January 1990. The MNS was to be fully satisfied by an endurance UAV generically labeled the Tier III. In July 1993, the Defense Science Board (DSB) determined that existing Tier III program concepts were either too expensive or unable to satisfy the RSTA capability. The parallel Tier II+/Tier III– approach was then substituted for the Tier III, providing the capability through a high/low force mix of complementary systems. In April 1994, DARPA, in conjunction with DARO, embarked on the develop-

ment of two HAE UAV systems: the Tier II+ (which became Global Hawk) and the Tier III– (which became DarkStar).

The basic organizational and acquisition strategy of the two HAE UAV programs evolved during the same period in which the ACTD process was being formulated, and there was close coordination between the principals of both activities during the 1993–1994 time frame. Although both HAE UAV programs were initiated before the ACTD process was formally introduced, both were included in the list of projects that made up the initial ACTD portfolio. A formal memorandum of understanding (MOU) designating the HAE UAV program as an ACTD was issued in October 1994.

One major consequence of designating the two HAE UAV programs as an ACTD was that the programs could be started without going through the elaborate and time-consuming process typically required for Acquisition Category (ACAT) I and ACAT II programs as described in DoD Directive 5000.1 and DoD Instruction 5000.2. Those traditional management procedures are based on the assumption that relatively large forces of a new system will be produced and employed in well-understood ways, thereby justifying extensive front-end planning and coordination. An ACTD program, however, offers an opportunity for radically new system concepts to be developed through a process whereby operational employment tactics are developed along with the hardware, and the overall effectiveness of the system is not judged until operational trials are conducted. Thus, somewhat less front-end planning and coordination is necessary before program initiation, and critical decisions are pushed downstream to a point at which demonstrated performance capabilities are available.

DARPA's management of the front end of this program was highly unusual. DARPA, an agency charged with technological innovation, is not in the business of developing new system concepts. Nevertheless, DARPA was expected to complete the design and build of the first two examples of each system and to prove the basic flightworthiness of each. DARPA was then expected to transfer both development efforts to the Air Force. The Air Force, which initially had no stated requirement, budget, or interest in either system, was to complete the ACTD. This plan strikes us as high risk.

The Standard Acquisition Process

In the acquisition of any complex system using the traditional (or standard) process, a plan is created at the beginning of each program phase (concept exploration, dem/val, EMD, and production). These plans describe what is to be done and in what order, how long each activity is to take, and what resources are to be applied to each task. In aggregate, these plans lay out for each phase the overall budgets, both annually and in total; the schedule leading to phase completion; and the activities that must be accomplished to meet the criteria to move to the next program phase. Underlying this process are the technical specifications of the system to be developed, which are based on an approved operational requirements document (ORD). These specifications are intended to ensure that the system will have the inherent ability to accomplish the missions for which it is intended.

The initial plan is a starting point that is adjusted as the program moves through each phase. As a phase is executed, extreme pressure is brought to bear to stay within annual budgets because additional funding is difficult to attain in any specific year. When programs encounter unanticipated difficulties, which all do, the fixed annual budget forces program task schedules to slip. This causes the total program length to grow, which is considered undesirable but tolerable. Total program cost also grows as the program consumes all annual budgets originally laid out as well as the budgets that were added as a result of schedule slip. The increase in total cost is also tolerated. All originally intended activities are eventually completed, and the program is then ready to move into the next phase of the acquisition process.

Sometimes there is extraordinary pressure to stay within a specified overall budget. This usually comes in the form of a congressional cost cap. However, the cost cap is usually imposed only after the program has been operating for some time and has already experienced significant overall cost growth. As development efforts progress, uncertainty and therefore risk diminish. By the time Congress steps in, much of the uncertainty and risk have been mitigated. Because of the typical timing of this process, the cost cap can usually be accommodated. Programs under congressionally mandated cost caps are usually completed with only minor adjustments

to what was to be accomplished within the developmental phase. Staying within initial schedules is seldom mandated and therefore occurs only rarely.

When the standard acquisition approach is used, program phases are not concluded until a system has exhibited all required capabilities and until all activities specified for phase completion have been carried out. The technical specifications that underlie the system's ability to perform the missions for which it is intended are strictly adhered to. However, it is common to compromise on a few detailed technical specifications when the original ones are not attained cost-effectively or if they prove to be technologically infeasible. This is acceptable only when the specifications that have been attained are sufficient to ensure that the system's ability to conduct its mission will not be materially affected. Regardless of the technical capabilities attained, it is not common to move forward to the next program phase until all specified tests have been conducted and all capabilities have been demonstrated—even if these capabilities represent slight modifications in those laid out at the phase's inception.

The HAE UAV ACTD Acquisition Strategy

Priorities were different in the HAE UAV ACTD program. In this instance, the need to stay within the initially estimated total program cost and schedule was placed above accomplishing all the activities set out at the program's inception and above achieving the technical characteristics of the system to be developed. The ACTD plan gave the program a total budget that was treated as a firm cap as well as a schedule with a firm end date. Although in a strict sense neither of these constraints was met, both were only slightly exceeded, and the program was brought to a conclusion even though it had not accomplished all the tasks set out for it at its inception. A decision was made to move into the next program phase without completing all desired activities.

Unlike the standard acquisition approach, the ACTD also mandated that the system demonstrate its capabilities in an operational environment. This activity was part of the original plan and fell within the fixed budget and schedule. The system was tested to see if those technical characteristics that had been attained could provide a mili-

tarily useful capability as well as to determine if the system could perform its intended missions. The idea was to ascertain which activities could be accomplished and which technical specifications could be attained within a given total budget and schedule.

PROGRAM DESCRIPTION: THE PLAN

Although managed under the same umbrella DARPA joint program office, the Tier II+ and Tier III– systems had distinct origins and plans. The contractor teams for the two air vehicle systems had minimal interaction with each other. Flight testing of the two systems was expected to include each system individually along with combined missions using both. The two systems were developed under a highly innovative management approach consisting of seven interdependent elements:

- The ACTD designation bound cost and schedule, provided for a streamlined oversight process, and allowed for early user participation.
- Use of the OTA provided a blanket waiver of all acquisition regulations, resulting in a more flexible and responsive contracting vehicle.
- The use of IPPD/IPT processes and structure eventually led to a close and collaborative working relationship between government and contractor.
- Contractors were vested with considerable management responsibility and authority, resulting in faster decisionmaking and in the use of contractor rather than government-mandated processes.
- The establishment of a single requirement, UFP, with all other performance elements stated as goals, expanded the trade space open to system designers and served as a way to control costs and requirements.
- Early user participation provided an operational flavor to flight test activities and kept the program focused on the primary objective of demonstrating military utility.

- A small program office provided added flexibility and responsiveness on the government side.

Tier II+ Global Hawk Program Plan

The HAE UAV Tier II+ program plan consisted of four phases, as depicted in Figure 2.1. According to the HAE UAV Phase I solicitation dated June 1, 1994, the planned program structure was as follows:

- **Phase I:** A six-month effort by three contractor teams to conduct a System Objective Review and a Preliminary System Specification Review.
- **Phase II:** A 27-month effort by two contractor teams to design and develop the Tier II+ system, complete the definition of the system specification and all interfaces, produce a prototype system, and successfully complete initial flight testing. The products were to be two prototype air vehicles, one set of sensors, a prototype ground segment, and a support segment capable of demonstrating initial system performance.
- **Phase III:** A 36-month effort by a single contractor team with the primary objective of the successful operational demonstration of the Tier II+ system. The products were to be eight preproduction air vehicle systems fully integrated with all subsystems and sensors (except for two electro-optical/infrared [EO/IR] sensors); two ground segments capable of supporting the air vehicle segments; and the provision of logistics support and planning for a user-conducted two-year field demonstration of the Tier II+ system. This phase would include an irrevocable offer to supply ten air vehicle segments under Lot 1 of Phase IV for the recurring UFP of $10 million in FY 1994 dollars.
- **Phase IV** called for open-ended serial production of air vehicles 11 and subsequent and ground segment 4 and subsequent.

The program plan called for Phases I–III to be completed between October 1994 and December 1999 for a total program length of 63 months. During Phases I and II—those in which DARPA was to manage the program—multiple contractor teams were to compete for work in the following phase. The competition was to substitute

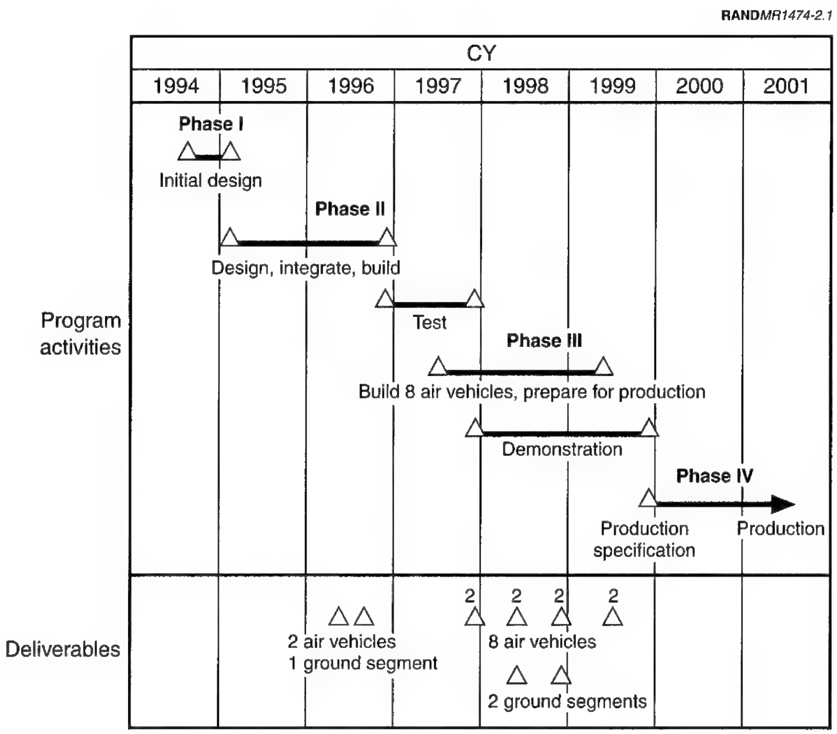

Figure 2.1—Tier II+ Schedule, Original Program

for close government management oversight. This substitution was all the more important given DARPA's inexperience in managing system development efforts.

Phases II and III were to be executed concurrently for six months in 1997. At the end of the Phase III demonstration, the apparent expectation was that the design would be ready for immediate serial production and operational use in Phase IV. The program schedule and budget as originally defined made no provision for the kind of detailed engineering needed to prepare a design for production and operation.

Planned annual contractor funding for the program's first three phases, as outlined in the Phase I solicitation, is shown in Table 2.1. Phase IV funding is not shown because the decision to produce

Table 2.1

Tier II+ Program Obligation Plan (millions of TY dollars)

Phase	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	Total
Phase I	12							12
Phase II		70	110	50				230
Phase III				70	130	50	20	270
Total	12	70	110	120	130	50	20	512

would be made at a later date, and production was to take place after the conclusion of the ACTD—if at all.

Tier III– DarkStar Program Plan

The Tier III– program was a sole-source effort from its inception. The DARPA program office elected to award the Tier III– program to the Lockheed/Boeing team on the basis of its prior work related to the Tier III concept. The Lockheed Advanced Development Company, also known as Lockheed Martin Skunk Works (LMSW), was the lead contractor for the Tier III– effort. DARPA had a history of allowing this particular division of the Lockheed Corporation unsurpassed autonomy in executing technology demonstration aircraft programs, and DarkStar was no exception. Government oversight was not an issue, as DARPA assumed that the contractor knew what to do and would get the job done. Elements of the program were designated special access, and details were withheld from the public until the rollout of the first air vehicle almost a year into the program (June 1, 1995).

The initial Agreement between the program office and Lockheed was signed in June 1994, before DARPA and DARO had completed the process of defining the complete Tier III– program structure. As a result, the Agreement simply defined the initial phase of the program. It called for the design and production of two proof-of-concept flight vehicles, one radar sensor, one electro-optical (EO) sensor, data links, and one launch, control, and recovery station (LCRS). Funding was set at $118 million to $125 million. No specific follow-on activities were described, but the Agreement stated the desire to rapidly

and cost-effectively transition into production. The schedule goal for the phase was 21 months, aiming for completion in March 1996.

In July 1994, DARPA and DARO signed an MOU that defined a more complete Tier III– program, as shown in Figure 2.2. The MOU stated that DARO would be the Office of the Secretary of Defense (OSD) sponsor and that the agency was to execute the program as an "ACTD/ACTD-like program." The content of the Agreement signed with Lockheed the month before was designated the Baseline Program. A follow-on Demonstration Option phase was specified in the MOU.[1] This phase called for the development of two to four additional air vehicle systems. As in the Global Hawk program, the apparent expectation was that at the end of the Demonstration Option phase, the design would be ready for serial production and operational use immediately following the ACTD. The program schedule and budget as originally defined made no provision for the kind of detailed engineering needed to prepare a design for production and operation.

The estimated total cost for all systems, associated support, and field demonstrations for both phases was first stated in November 1994 and is shown in Table 2.2. DARPA was to provide $87 million, while DARO was to provide $130 million. As in the Global Hawk plan, production funding was not shown, as the decision to produce was to be made at a later date, and production was to take place after the conclusion of the ACTD—if at all.

The Common Ground Segment

Each air vehicle system required a ground segment to control the air vehicle and to coordinate the collection and dissemination of its imagery. These two functions were split into two elements in each program. For Global Hawk, the functions were accomplished by the

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[1]In other parts of this document, these phases are referred to as Phase II and Phase IIB, respectively.

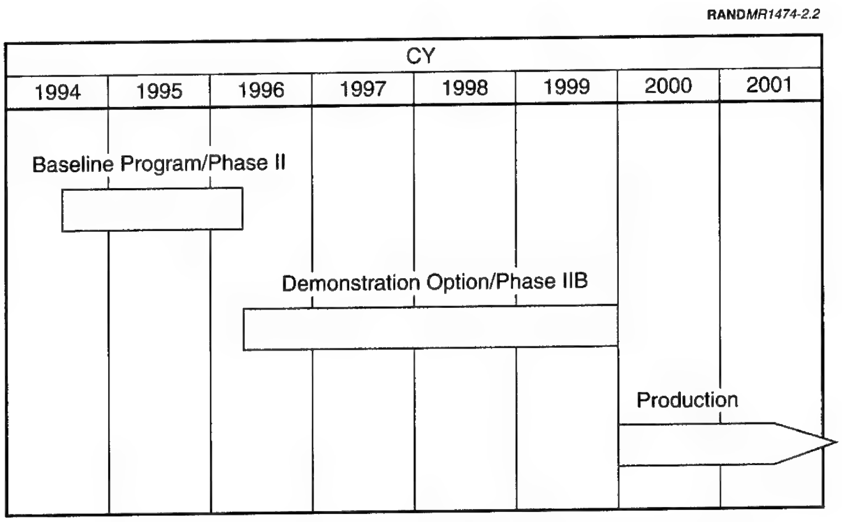

Figure 2.2—Tier III– Schedule, Original Complete Program

LRE and the MCE. Teledyne Ryan Aeronautical (Ryan)[2] subcontracted the design and build of these elements to Raytheon E-Systems (RayES). For DarkStar, the two functions were provided by the LCRS and the processing and display system (PDS).

Not in the original program but part of the early planning process was the concept of merging the ground segments of the two HAE

Table 2.2

Tier III– Program Obligation Plan (millions of TY dollars)

Phase	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	Total
Baseline Program/Phase II	32	60	29.5				121.5
Demonstration Option/ Phase III/Phase IIB			20.5	45	15	15	95.5
Total	32	60	50.0	45	15	15	217.0

[2]Known as Northrop Grumman Ryan Aeronautical Center beginning in June 1999. This contractor is simply referred to as "Ryan" throughout the balance of this document.

UAVs into a single element both for air vehicle control and for imagery management. In January 1996, when RayES was directly contracted to integrate DarkStar's ground segment functionality into Global Hawk's LRE and MCE, this concept became the CGS.

The ACTD Planning Disadvantage

In the standard acquisition approach, Milestone I usually calls for the building of two air vehicles in a dem/val or prototype phase. Plans are laid out for that phase and it is then executed. Estimates for EMD may be requested at that time, but these estimates are not detailed; nor are they put on contract. Typically nonbinding, they are more of a sizing exercise than a formal requirement.

When dem/val is complete, a Milestone II decision is made. At that point, the basic concept's fundamental design uncertainty is diminished, the initial design and test effort having been completed in dem/val. The two air vehicles already built and flown provide a strong sense of what works and what does not in the system's overall architecture and configuration. This experience informs the detailed planning for the EMD, which is done at Milestone II. The estimates for EMD at this point are put on contract.

The HAE UAV ACTD was forced to plan its entire six-plus-year development effort at its inception. This effort amounted to the equivalent of a dem/val program, followed by an abbreviated yet de facto EMD, followed by the rough equivalent of an initial operational test and evaluation (IOT&E) program. The program did not have the benefit of planning costs and schedules just for the first two air vehicles. Instead, planning or at least determining the scope of the abbreviated yet de facto EMD was required before lessons could be learned from the design, build, and test of the first two aircraft.

Because the uncertainty and risk were so great early in the program, this approach put the entire developmental planning process at a major disadvantage. This disadvantage might not have been crippling had the development of the HAE UAVs been simply a matter of integrating mature technologies. Instead, both HAE UAVs were all-new system types that required sophisticated system integration and software development efforts. The DarkStar program had the added

challenge of developing a radically new planform or airframe shape to achieve multiaspect low observability.

However, this planning disadvantage was compensated for in other parts of the strategy. The inherent flexibility of the OTA, for example, along with the focus on demonstrating military utility rather than on meeting a long list of technical performance capabilities, provided an opportunity for the program office and the contractor to continuously adjust their approach in the execution of the program. The program's outcomes suggest that the original plan was not as important as would have been the case had the traditional acquisition approach been used. The inherent flexibility of the strategy was essential to Global Hawk's success.

PROGRAM DESCRIPTION: WHAT HAPPENED

The program office received 14 proposals for the Tier II+ Phase I effort. Given the breadth and quality of these responses, DARPA selected five rather than the planned three contractors to perform the Phase I task. Each contractor team received a fixed amount of $4 million, and the six-month phase was begun and completed as scheduled.

The original plan as well as the expectation of Phase I participants was that two contractors would be awarded agreements for Phase II (and thus two systems designed and flown). During Phase I, however, DARPA revised its plans for Tier II+ Phase II. As shown in the Phase II solicitation, funding was reduced from the original $230 million to $164 million. This funding reduction forced the program office to choose to cancel the program, change the activity content of Phase II, or downselect to only one Phase II contractor. The program office chose the last option, and competition within the Tier II+ program was thus eliminated.

DARPA did not change the oversight process to account for its loss. The agency did state that the Tier II+ system was now in competition with the Tier III– system (the existence of which had recently been disclosed) both for future funding and, ultimately, for the force mix decision. Should one system not meet expectations as it was developed, its failure could—and, in the case of DarkStar, ultimately did—lead to cancellation and to the transfer of all remaining funding to

the other program. Should both systems complete the ACTD and attain positive military utility assessments (MUAs), the split of production between the two HAE UAV systems—i.e., the decision as to how many of each would be produced—would depend in part on their relative performance.[3]

Despite this new approach toward injecting competition into both HAE UAV programs, the early elimination of competition within the Tier II+ program proved controversial. The four Phase I contractor teams that were not selected to continue in the program were especially unhappy with this decision. In their minds, Ryan was the odds-on favorite, and they thus believed that they were competing for the runner-up slot. When this slot was eliminated midway through Phase I, they felt that their chances of being awarded the Phase II work had been diminished to near zero.

Dem/Val Equivalent: Phase II

The dem/val-equivalent effort in each of the programs—i.e., the design and build of the first two UAVs of each type in Phase II—went greatly over budget and took much longer than anticipated.[4] These initial major development efforts essentially contained all the activity envisioned at their inception plus some additional tasks to bring about the CGS.[5]

This phase in the Global Hawk program cost some 50 percent more than originally budgeted, from its initial estimate of $158 million to a

[3]An 80 percent Tier II+/20 percent Tier III– force mix was assumed, but this could be altered to some extent if one or both of the systems were significantly more capable or less capable than expected.

[4]A detailed description of the activity content and its evolution over time is contained in Appendix B.

[5]Both the Global Hawk and DarkStar programs lost one of their first two aircraft in flight. When we compare program expectations to outcome in this report, we do not adjust the outcomes to reflect the lost air vehicles. In other words, the contractor did the work to make the aircraft flyable thus the contractor is given "credit" for doing so. We choose this approach because aircraft losses are not unexpected in prototype or dem/val programs. The ramifications of the losses are indirectly reflected in other program outcomes, such as schedule slips and the ability to conduct flight test and demonstrations.

final cost to the government of about $238 million.[6] The additional costs were absorbed through changes in what was to be accomplished in subsequent phases of the ACTD; thus, no additional funding was required to complete Phase II. The schedule for the effort increased from an estimated 27 months to a final length of roughly 45 months, representing a 67 percent increase in schedule length.[7] At the end of the phase, the effort was essentially a success. The apparently poor cost and schedule performance of the Global Hawk Phase II program in comparison to the original estimate was due primarily to four factors:

- Initial estimates were unrealistically low;
- The contractor did not initially appreciate the complexity of the system to be developed;
- The DARPA program office allowed the contractor to assume a high-risk development effort; and
- Sufficient expertise for basic system development was not attained by the contractor until well into the effort.

In the DarkStar program, costs for Phase II ran about 80 percent over, from an initial estimate of $122 million to a final cost of $220 million.[8] This outcome is not as poor as it might seem given that almost one-third of the overrun stemmed from contracting with RayES for the added activity of creating the CGS to replace DarkStar's indigenous ground segment. The schedule for the effort increased from an estimated 21 months to a final length of 54 months, representing a 157 percent increase in schedule length.[9] At the end of this effort, the system had not yet matured to the point of basic func-

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[6]This final cost includes payments to both Ryan and RayES that are considered part of Global Hawk Phase II. For a complete definition of the CLINs in this phase, see Appendix A. For a detailed breakdown of CLIN costs and their increases over time, see Appendix B.

[7]Detailed schedule growth information by phase is contained in Appendix C. Detailed schedule time lines by CLIN are contained in Appendix A.

[8]This final cost includes payments to both LMSW and RayES that are considered part of DarkStar Phase II. For a complete definition of the CLINs in this phase, see Appendix A. For a detailed breakdown of CLIN costs there increases over time see Appendix B.

[9]See Appendix B, note 9.

tionality. Hence, the effort cannot be characterized as a success. The poor cost, schedule, and technical outcomes of the DarkStar Phase II program in comparison to original estimates were due primarily to three factors:

- Initial estimates were unrealistically low—even more so than in the Global Hawk program;
- The contractor pursued cost and schedule goals even more challenging than those laid out by the government, which led to an inherently poor design and to the elimination of key system development tasks; and
- The DARPA program office allowed the contractor to assume a high-risk development effort—again, even more so than was the case in the Global Hawk program.

Follow-on Development Asset Production, and Design Evolution

The HAE UAV ACTD's Other Transaction (OT) designation allowed the program office and contractors the freedom to contract for additional work or to change emphasis or direction as needed. In both the Global Hawk and DarkStar programs, nonrecurring engineering efforts to improve the design and to manufacture air vehicles 3 and subsequent were put on contract without initial cost estimates.[10] Only after the work was well under way and both the program office and the contractor had gained a good understanding of what was desired in this follow-on phase—deemed Phase IIB—were prices set for these efforts.[11]

In both programs, it was viewed as advantageous and necessary to contract for follow-on air vehicle manufacture before the completion of Phase II. The advantage was manufacturing continuity. Had government and contractor program managers waited for the completion of Phase II before beginning Phase IIB, a significant gap between

[10]For a detailed account of nonrecurring engineering activities, air vehicles built, and sensor suites procured in Phase IIB of each program, see Appendix B.

[11]For a detailed account of incremental Phase IIB seed funding and final phase definition and pricing for each program, see Appendix B.

the manufacture of air vehicles 2 and 3 would have occurred. The fixed end date for the ACTD, coupled with the huge schedule overruns in Phase II of both programs, made it necessary to order follow-on aircraft before the end of Phase II. If additional aircraft had not been ordered until the completion of Phase II, only the first two air vehicles would have been available for the operational demonstration. As it turns out, only one aircraft would have been available in each program as a result of the loss of one in each program prior to the commencement of operational demonstrations.

Funding and activity for Global Hawk Phase IIB began in August 1997. The program office put on contract those activities that were affordable, which amounted to a small fraction of those envisioned at the beginning of the Tier II+ program. Ryan, the Global Hawk prime contractor, was to build three aircraft and one integrated sensor suite (ISS), perform a multitude of integrated logistics support (ILS) tasks, provide ILS equipment and supplies, and conduct nonrecurring engineering studies and design efforts. The CGS prime contractor, RayES, was put on contract in Phase IIB for the second MCE, the second and third LREs, and enhancements to the mission planning system. These efforts contributed to both the Global Hawk and DarkStar programs. Phase IIB was initially priced in March 1998.

Another ISS was added to the Ryan statement of work (SOW) later in the phase, when more funding became available and the need to equip an additional aircraft with sensors for the operational demonstration had become clear. This addition accounted for almost all of the cost growth and schedule slip in Global Hawk's Phase IIB effort. In March 1998, it was estimated that the phase would be complete by December 1999. As a result of added content, the cost of the phase grew from $120 million in March 1998 to $134 million at its completion in September 2000, and the schedule grew from an initial 29 months to a final length of 38 months.

Funding and activity for DarkStar Phase IIB began in November 1996. As in the Global Hawk program, the program office put on contract those activities that were affordable, which amounted to a fraction of those envisioned at the beginning of the Tier III– program. Lockheed was contracted to build air vehicles 3 and 4 along with one EO and one synthetic aperture radar (SAR) sensor payload. Minor design changes were called for in the air vehicles at the time the ef-

fort was first defined. Multiple studies were specified, and contractor ILS was continued from Phase II.

As a result of the poor aerodynamic characteristics of the first two DarkStars, significant additional design changes to air vehicles 3 and 4 were called for later in Phase IIB.[12] These changes caused more than half the cost growth in this phase. Long-lead items for air vehicle 5 and efforts to improve the EO sensor were added later, significantly contributing to cost growth in the phase. As stated above, portions of work contracted for with RayES also contributed to the DarkStar program. There was virtually no cost growth in these efforts.

The cost of DarkStar Phase IIB grew from $80 million when it was initially defined in May 1997 to $104 million at its administrative closeout in April 2000. At the end of January 1999, the program was officially canceled and activity halted. Air vehicles 3 and 4 were delivered, but neither ever took flight, calling into question their flightworthiness. The activities of the phase were not complete at the time of program cancellation. It is not known, however, how much more the government would have had to pay to complete Phase IIB. Because the schedule for Phase IIB was never specified, we cannot put a lower bound, much less estimate an upper bound, on the amount of schedule slip that characterized the effort.

The program's cancellation prevented the single flightworthy DarkStar aircraft[13] from participating in the Phase III operational demonstration.

DarkStar's Cancellation

The Oversight Integrated Product Team (OIPT) reviewed the HAE UAV program on January 19, 1999. On January 22, the OIPT made a

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[12]The LO characteristics of the first two DarkStar air vehicles were not released. We do not know to what extent the design of air vehicles 3 and subsequent was altered as a result of LO deficiencies.

[13]It is possible, even probable, that three DarkStar aircraft would have been available for the demonstration and evaluation (D&E) program. However, the flightworthiness of air vehicles 3 and 4 was not determined at the time of program cancellation; thus, we cannot assume that they would be usable in the D&E.

recommendation to an Executive Review chaired by the Under Secretary of Defense for Acquisition and Technology (USD[A&T]) and the Vice Chairman of the Joint Chiefs of Staff (VCJCS) that led to the decision to terminate DarkStar. The Air Force concurred in this decision at senior levels. Some senior Air Force decisionmakers did not want DarkStar to transition from DARPA in October 1998. In fact, the planned termination of DarkStar was put in motion as early as August 1998. At that time, a decision was made to spend out the remaining $7.5 million in government funds before the required contractor matching funds were spent. DarkStar was in a serious cost-overrun and was thus sharing the costs of continuing efforts. Any additional contractor cost-share funds constituted actual outlays rather than reduced profit. This spend-out plan was embedded in DarkStar's agreement amendments.

According to some observers, the Air Force never really liked DarkStar: Its payload was considered too small, its range too short, and its configuration not sufficiently robust. However, DarkStar did attempt to satisfy a validated mission need for a stealthy reconnaissance vehicle. That mission need remains unsatisfied.

Many factors contributed to the cancellation of DarkStar. One fundamental problem was that Boeing made mistakes in its early simulation and wind-tunnel tests—mistakes that were most likely due to limited wind-tunnel testing of the air vehicle's radical design. Aggressive management by the contractors ultimately led to the destruction of the first air vehicle. DarkStar management was too cautious thereafter in an overreaction to the crash of the first air vehicle. Neither government nor contractor management wanted Air Force involvement in DarkStar's flight testing, and both made that explicit in their interactions with the 31st Test and Evaluation Squadron (TES).[14] The 31st TES was actively excluded from the program (there was no contractual obligation to include them) until the end of the program. Contractor program management asked for help at the last minute.

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[14]The Air Force's 31st TES assisted Ryan's execution of the flight test program at Edwards Air Force Base. For a complete account of their involvement, see Jeffrey A. Drezner and Robert S. Leonard, *Innovative Development: Global Hawk and DarkStar—Flight Test in the HAE UAV ACTD Program*, MR-1475-AF, Santa Monica: RAND, 2001.

Finally, indications are that the relationship between LMSW and Boeing had deteriorated over time, interfering with the quality of their work. The contractor program management was described by LMSW as having "collapsed" by the end. However, the main factor was likely affordability: The HAE UAV had been added to the Air Force's ISR program without additional funding. The Air Force decided that it could not afford to go forward with two different UAVs at this time. The termination of DarkStar soon after the management transition from DARPA to the Air Force enabled the Air Force to focus its efforts on a single HAE UAV system.

Most observers agree that DarkStar was ahead of Global Hawk in terms of the maturity of its SAR and EO/IR sensor payloads but less mature in terms of its air vehicle design. LMSW management did not deviate from their flight test plan to take imagery early and thus demonstrate the system's sensors. Had they done so, the program might have been saved by the subsequent support generated for it, specifically from Congress. The contractor team was in a position to take pictures using DarkStar in October 1998 but chose instead to further expand the flight envelope. Some program participants believe the contractor team became too cautious and was therefore unwilling to put sensors onboard the air vehicle.

The LMSW/Boeing team did not anticipate the oscillation of the second DarkStar aircraft during flight testing. The problem was apparently controlled in the last two flights before the program ended. Some program participants considered the program's cancellation a mistake; they believed that the air vehicle's basic aerodynamics were sound enough to justify finishing out the ACTD. They noted that the knowledge attained from DarkStar's participation in Phase III demonstration and evaluation (D&E) would have been well worth the minimal additional expenditures (in fact, it may actually have cost more to close out the program early than to complete it).

The three surviving DarkStar vehicles were transferred to museums at Wright-Patterson Air Force Base, Eglin Air Force Base (UAV BattleLab), and Edwards Air Force Base. The Air Force never considered retaining them to support other experiments. Lockheed considered suing for $33 million (its cost share) plus the $9 million fee they would have earned, but ultimately they did not do so. During the months prior to formal closeout of the agreement, Lockheed

charged approximately $1 million per month for removing equipment, boxing materials, and the like. The final settlement is embodied in Amendment 0056 of the DarkStar Agreement, dated April 28, 2000.

Perhaps the most significant programmatic impact of the DarkStar cancellation was on the CGS. The concept of the CGS was to include the incorporation of DarkStar functionality into the Global Hawk ground segment. At the time of cancellation, most of the nonrecurring engineering tasks associated with this goal had been completed. The second LRE was at Boeing for final integration, and the second MCE was at Raytheon in the final stages of fabrication. Both had to be subsequently redesigned to remove the now-unneeded DarkStar functionality. Because of DarkStar's cancellation, the majority of work accomplished under the CGS contract through January 1999 was not demonstrated during the ACTD and will be of no use to the Global Hawk program.

Demonstration and Evaluation

The Air Force took over management of the HAE UAV in October 1998. Calendar time and funding for the ACTD were running out. Only 16 months remained if the effort was to conclude as planned in January 2000. Ryan's Global Hawk Phase III D&E proposal was initially priced and defined in December 1998. The proposed effort was priced at $64 million, with D&E flights involving all five Global Hawk air vehicles built in the preceding two phases. The contractor was responsible for operating the air vehicles and for managing imagery collection during D&E flights. The D&E activity in this plan represented a small fraction of the 24 months of operational demonstrations, utilizing ten aircraft that had been envisioned at the ACTD's inception. Nonrecurring engineering tasks and support were part of Phase III as well.

In March 1999, both Ryan's and RayES principal Phase III efforts were defined. The Ryan effort was priced at $45 million, with $37 million supporting D&E activity and the remaining $8 million for nonrecurring engineering tasks. A multitude of nonrecurring engineering tasks originally proposed by Ryan were deemed unnecessary; hence the lower price. The RayES effort was priced at $13 million for

D&E support only; no nonrecurring engineering activities were called for.

A few weeks before Global Hawk D&E flights were to begin, air vehicle 2, along with the only existing complete ISS, was destroyed when it received an unintended self-destruct signal. Its destruction delayed the initiation of D&E flights by two months. Air vehicle 1, carrying just the SAR portion of the ISS, had conducted 11 D&E sorties from June through October of 1999, when air vehicle 3, with a complete ISS, took over. At the end of its fifth D&E sortie and less than one month after beginning its participation in the D&E, the aircraft sustained heavy damage in a high-speed taxi accident—damage that included substantial destruction of its EO/IR payload. This removed the aircraft from the remainder of the D&E phase, thereby eliminating the only chance of obtaining useful EO/IR imagery during the ACTD. The EO/IR sensor payload had not been sufficiently "characterized," or fine-tuned, to provide useful imagery prior to the taxi accident. D&E flights did not resume for over four months, when air vehicle 4 conducted five D&E sorties in April and May of 2000.

It appears that the scope of D&E flight activity defined at the beginning of Phase III—that is, ten months of flights—was considered the minimum required to provide sufficient data to perform the MUA called for at the ACTD's completion. Each of the delays in D&E flight testing resulted in a extension of the end date of the activity, causing the only significant departure from the firm ACTD schedule end date as defined in 1994. At the end of D&E activity, three aircraft during nine months (over a 12-month period) flew some 21 sorties for a total of 381 flight hours.

Between May 1999 and April 2000, a series of nonrecurring engineering activities were added to Ryan's Phase III effort. Some $22 million was added to the basic effort, additional funding was committed to studies and analyses, and $19 million was added for the building of a development test model (iron bird) and for making tooling improvements. The studies and analyses provided preparation for improving the system's design in yet-to-be defined follow-on development efforts. The development test model preserved a minimal core production capability at Ryan, thereby ensuring that follow-on air-

craft could be built by a workforce retaining some of the experience gained in the ACTD. These efforts stretched into February 2001.

The cost growth in Phase III resulted from additional nonrecurring engineering activity requested of Ryan. The total went from $77 million, combining the late 1998 Ryan and early 1999 RayES initial prices, to an estimated $109 million as of August 2000. The schedule for D&E flights was slipped to ensure that sufficient data were available to inform the MUA. The start date slipped from April 1999 to June 1999, and the completion date slipped from January 2000 to May 2000.

The completion date for Phase III nonrecurring engineering activities slipped as well, but this too was driven by the content added during the phase. This added content resulted from the success of the program: Had the system not performed well, the contractor and program office would have been preparing to close out the effort rather than pursuing improvements to the system. The schedule extensions had become irrelevant by the summer of 1999 when a post-ACTD development effort became almost certain.

THE ACTD's FLEXIBILITY LED TO GLOBAL HAWK's SUCCESS

At their most aggregate level, ACTD programs are intended to provide a means for the rapid, cost-effective demonstration of new capabilities. Given a positive MUA, an ACTD should accelerate the introduction of these capabilities into the military services. Most program participants believe that the Global Hawk program achieved this goal. Most also believe that this objective would not have been met in the DarkStar program even if it had been allowed to complete its ACTD program.

In the sense of what was envisioned at the beginning of the program compared to what occurred, the activity content of the ACTD was greatly curtailed while both the cost and schedule of the total effort grew only slightly. What occurred in effect was a continuous change in activity content throughout the ACTD in an attempt to stay within the original total cost and schedule constraints defined at its inception. Nevertheless, these changes did not adversely affect the ability

of Global Hawk to demonstrate sufficient military utility to merit a positive assessment.

The inherently uncertain and risky design, build, and basic testing of the first two aircraft ended up consuming a much larger portion of the allotted budget and calendar time than was called for in the initial ACTD plan. To stay within these constraints, the planned development and testing efforts were greatly curtailed. As a result, not all the operational capabilities that the system might have been capable of were given sufficient opportunity for demonstration.

The tasks accomplished in the HAE UAV ACTD brought the Global Hawk system to a level of developmental maturity not equivalent to any milestone in the standard acquisition process. The HAE UAV ACTD is accurately described as much more than a dem/val program but not a complete EMD program. At the end of the HAE UAV ACTD, Global Hawk was not a fully developed system. It was not ready for production and did not demonstrate all that was called for in the ACTD. However, the system was well along in development. Moreover, it showed the potential to be operationally suitable and militarily useful given a follow-on EMD program taking a small fraction of the time and funding normally required in a traditional EMD program.

Chapter Three

ONE REQUIREMENT: UNIT FLYAWAY PRICE

A cornerstone of the HAE UAV ACTD program's acquisition strategy was a single requirement: the air vehicle UFP of $10 million as measured in FY 1994 dollars. The HAE UAV joint program office, under the guidance of the Deputy Under Secretary of Defense for Acquisition and Technology (DUSD[A&T]), decided to approach the problem of UAV system cost growth through this new approach. In early 1994, following program initiation but prior to the first contract award, the UFP requirement was adopted as part of the HAE UAV acquisition pilot program. This requirement was imposed before the program's October 1994 designation as an ACTD.

The requirement was codified with the associated "irrevocable offer" article included in the initial Agreements with the Tier II+ and Tier III– prime contractors. The irrevocable offer demanded ten air vehicles, units 11–20, for a total cost to the government of $100 million. The UFP requirement was reiterated throughout the body of initial program management documents. As illustrated below, it would be difficult to overstate the emphasis placed on this single requirement at the program's inception.

The second paragraph of DARPA's "Memorandum for HAE UAV Bidders," dated June 1, 1994, reads: "Our objective is to demonstrate that the Tier II+ system will be affordable and the air vehicle can be purchased for [a] $10 million unit flyaway price (UFP). This is such a significant objective that we have established the UFP as the only threshold requirement. The discretion we are giving you to define the Tier II+ system is unprecedented. The complement to this is our unequivocal commitment to the $10 million UFP."

The initial DARPA SOW for the Tier II+ program reads similarly: "There is a firm threshold that the unmanned air vehicle (UAV), high altitude endurance air vehicle, be designed to a $10 million (FY94 dollars) recurring unit flyaway price (UFP) for each air vehicle system. The $10M UFP includes all flight hardware, including airframe, avionics, sensor(s), communications, integration, and checkout, and is the total price paid by the government, including profit."

"Article 18: Irrevocable Offer," included in the Agreement signed between Ryan and DARPA in early November 1994, reads, "TRA [Ryan] is required at the completion of Phase II to provide an irrevocable offer under which the Government may buy 1 lot of 10 each air vehicles (Phase IV) as described in the System Specification developed in Phase II at a firm fixed price of $10 million each at FY 1994 Base Year Dollars."

"Article 17: Irrevocable Offer," part of the Agreement signed between Lockheed and the government on June 20, 1994, invoked the UFP in the Tier III– program. The irrevocable offer regarding air vehicles 11–20 was to be requested upon the ordering of air vehicles 6–10. When and under what program construct these air vehicles were to be ordered was not stated.

WHY THE UFP?

The history of cost growth in prior UAV programs—particularly unit flyaway cost growth—is believed to be the primary motivation underlying the UFP requirement in the HAE UAV ACTD program. One of the prominent difficulties encountered by earlier UAV programs lay in the fact that unit costs tended to escalate so much during development that the resulting systems cost more than users were willing to pay, precipitating program cancellation in almost every case.

This problem is not unique to UAVs but has been more acute in these programs than in other system development efforts of the past several decades. Two circumstances unique to UAVs have contributed to their propensity for above-average unit cost growth and program cost growth in general:

- Unrealistically low initial unit cost estimates resulting from the "model airplane" origins of UAVs. Vietnam War–era UAVs were unsophisticated drones. This perception persists even today.
- Significant requirements creep during development. This occurs to a greater extent in UAV programs because their mission area is usually not predetermined and because they do not usually replace an existing system. As a result, potential system requirements are not constrained, which practically guarantees additions to those requirement laid out at the program's inception.

DEFINING THE UFP

The UFP was defined in such a way as to complement the irrevocable offer. Included under the UFP was a subset of what is normally thought of as unit cost. The unit cost metric customarily quoted in air vehicle acquisition programs is Unit Flyaway Cost, or simply Flyaway Cost. As shown in Figure 3.1, Flyaway Cost includes all direct and indirect manufacturing costs and their associated overhead plus recurring engineering, sustaining tooling, and quality control. Allowances or allocations to cover system and program management, software and other engineering changes and their associated test, and nonrecurring tooling, manufacturing, and engineering are also included.

The UFP definition used in the HAE UAV ACTD program, when compared to the customary Flyaway Cost term, excluded all the allowances and allocations along with sustaining tooling. The term included all items in the "Recurring Production Costs" box shown in Figure 3.1 except for sustaining tooling. As a result, the UFP is essentially but not exactly equal to recurring production costs. The reasoning behind defining this unique metric for the HAE UAV ACTD program was not explicitly stated in the program's literature, but we see likely motivations and find them to be well founded.

With the UFP applying to the air vehicles 11–20, the host of allowances and allocations normally included in Flyaway Cost would have contributed disproportionately to the UAV's reported unit cost had the traditional definition of Flyaway Cost been used. Software and other design changes tend to be concentrated near the beginning of a system's production run. Nonrecurring tooling, manufac-

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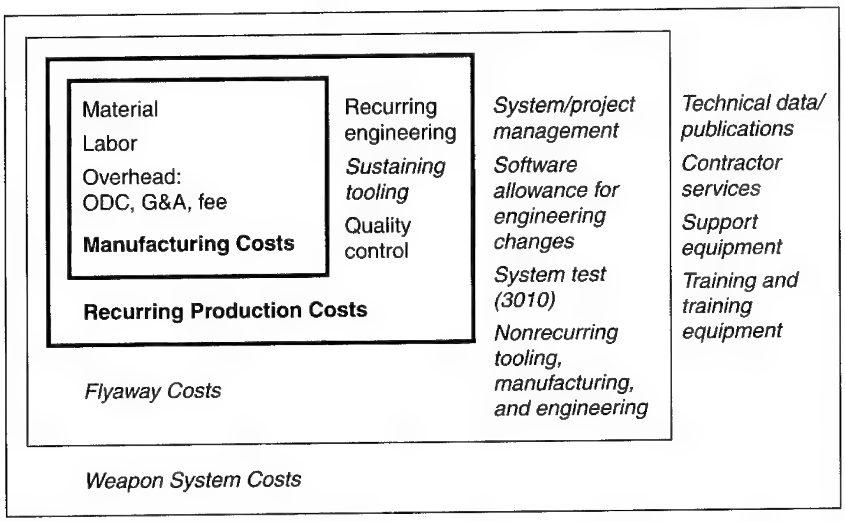

SOURCE: Global Hawk System Program Office (GHSPO) final UFP briefing dated March 2000. Only items in boldface are part of the UFP.

Figure 3.1—Perspective on UFP

turing, and engineering efforts are also concentrated near the beginning of the production run as production capability is ramped up to full rate. The relatively small number of air vehicles over which these costs would be allocated and the relative immaturity of the system at this early point in the production run would have inflated a reported Flyaway Cost.

Had the traditional Flyaway Cost metric been applied to these early aircraft, it would not have been representative of the true unit costs of the aircraft over its entire production run. The Flyaway Cost metric is more appropriately suited to targeting the cost of an entire production run numbered in the hundreds and spread out over the production program's life. Had the customary Flyaway Cost metric been applied to the HAE UAVs, the figure used could well have been double the $10 million for an air vehicle of equivalent capability.

GLOBAL HAWK UFP EVOLUTION

UFP estimates over time are broken out between the air vehicle and payload as shown in Figure 3.2. The $10 million UFP and its breakout quoted at the beginning of Ryan's involvement in November 1994 did not change in the first year and one-half of the program. Beginning in early 1996, the DARPA program office became skeptical of Ryan's reported numbers and began tracking the UFP. Estimates at differing confidence levels were adopted, with the 50 percent confidence level estimate placed at $10.9 million and the 90 percent confidence level estimate at $12.3 million as of June 1996.

In mid-1997, DARPA formally instituted UFP tracking by Ryan as part of the award of Phase IIB, which included building the third and fourth air vehicles. This was not the end of Phase II, but it was the point at which the second batch of air vehicles was ordered. In this respect, it resembled the point at which the irrevocable offer was to have been made. The Ryan Phase IIB SOW made no mention of the irrevocable offer.

In mid-1998, the U.S. General Accounting Office (GAO) reviewed the HAE UAV program to determine if the UFP would be attained.[1] The GAO's conclusion was that it would not. The original and July 1998 breakouts of the Global Hawk UFP are shown in Table 3.1. The final official UFP estimate released by the Global Hawk System Program Office (GHSPO) was Ryan's estimate of $15.3 million dated July 1999 as shown in Figure 3.2.

Under Air Force management—and in recognition of the reduced number of aircraft to be built during the ACTD and the consequent irrelevance of the UFP—the program formally abandoned both the $10 million UFP and the associated irrevocable offer on February 14, 2000. This occurred three days prior to the Agreement amendment

[1] See U.S. General Accounting Office, *Unmanned Aerial Vehicles: Progress Toward Meeting High Altitude Endurance Aircraft Price Goals*, GAO/NSIAD-99-29, December 1998. This report was required by Congress via the FY 1998 National Defense Authorization Act.

Table 3.1

Global Hawk UFP Estimates (millions of FY 1994 dollars)

Category	Original Estimate	July 1998 Estimate	Growth Difference
Structure	2.6	6.1	3.5
Avionics	0.4	0.5	0.1
Payloads	4.1	5.2	1.1
Propulsion	1.6	1.6	0.0
Fee	1.3	1.4	0.1
Total	10.0	14.8	4.8

SOURCE: DARPA HAE program office via U.S. General Accounting Office, *Unmanned Aerial Vehicles: Progress Toward Meeting High Altitude Endurance Aircraft Price Goals*, GAO/NSIAD-99-29, December 1998.

officially closing out Phase II and backdating that phase's completion to September 30, 1999. As stated by GAO in April 2000, the actual average UFP paid by the DoD in the future for the production version

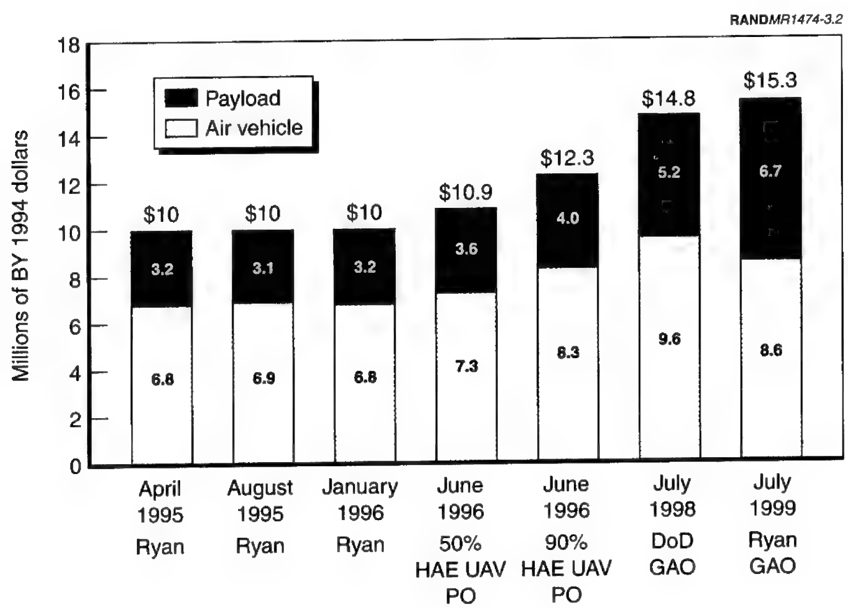

Figure 3.2—Global Hawk UFP Evolution (Units 11–20)

could be significantly higher than the $15.3 million quoted in mid-1999.

DARKSTAR UFP EVOLUTION

The evolution of DarkStar's UFP growth is less well understood. The GAO estimate as of July 1998 was $13.7 million. The growth from the original estimate of $10.1 million occurred primarily in avionics and payloads, as shown in Table 3.2. The July 1998 estimate is probably the final estimate made prior to DarkStar's termination.

DIRECT UFP EFFECTS IN THE HAE UAV PROGRAM

Controlling Requirements Creep

The UFP constraint shaped the system in both positive and negative ways. The UFP was invoked to successfully keep additional requirements (or "desirements," as the program had no official performance requirements) from being imposed. The program office under both DARPA and Air Force management used this tactic to control requirements creep. Every time an organization came to the program office with some new capability that it wanted to place onboard the air vehicle, HAE UAV program management simply referred to the UFP and stated that additional capabilities were not affordable. This

Table 3.2

DarkStar UFP Estimates (millions of FY 1994 dollars)

Category	Original Estimate	July 1998 Estimate	Growth Difference
Structure	4.8	5.5	0.7
Avionics	2.8	4.1	1.3
Payloads	1.2	2.4	1.2
Propulsion	0.5	0.6	0.1
Fee	0.8	1.1	0.3
Total	10.1	13.7	3.6

SOURCE: DARPA HAE program office via U.S. General Accounting Office, *Unmanned Aerial Vehicles: Progress Toward Meeting High Altitude Endurance Aircraft Price Goals*, GAO/NSIAD-99-29, December 1998.

allowed the program office to concentrate on its core program rather than complicate things or further stretch its already-thin resources.

The UFP and the overall ACTD budget cap were cited in refusing additional payload options. As with UAV programs that preceded Global Hawk, interest in the air vehicle, with its unique flight profile and endurance, grew quickly as soon as flight testing began in early 1998. Others saw the air vehicle as a potential "truck" that could carry their payloads of choice.

By the time the Air Force took over the program in late 1998, multiple potential payloads were being developed outside the HAE UAV ACTD. These were allowed to continue on what was described as a noninterference basis. The developers were told that their payloads would be considered for integration in EMD after the completion of the ACTD. Those payload developers that could fund the cost of integrating their payloads onto the aircraft would be the first to get a chance to do so.

As of July 1999, the following programs had shown interest in Global Hawk:

- The Advanced Synthetic Aperture Radar System (ASARS) Improvement Program, or AIP (a SAR of superior capability in comparison to the ASARS currently carried on Global Hawk)
- Airborne Communications Node (ACN)
- Bistatic Moving Target Indicator (MTI)
- Foliage Penetration (FOPEN) Radar
- Joint Air-to-Surface Standoff Missile (JASSM) Bomb Impact Assessment (BIA)
- Airborne Information Transfer (ABIT)
- Army Interferometric SAR Program (AITP)
- Joint Signals Intelligence (SIGINT)
- Nuclear, Biological, and Chemical (NBC) Detection
- Airborne Targeting and Cross-Cueing System (ATACCS)
- Unintentional Radiated Emissions (UREs)

- Multisensor Agile Reconnaissance System (MARS)
- Multispectral Imagery/Hyperspectral Imagery (MSI/HSI)
- Boost-Phase Intercept (BPI)
- Passive Air Surveillance Augmentation (PASA)
- Extended Air Surveillance (EAS)

Controlling Ryan's Costs

The UFP placed continuous pressure on the contractor to control costs, yielding both positive and negative results. As the program's only requirement, the UFP could be held over the contractor as paramount and could be credibly cited as leading to program cancellation if not met. While everyone expected that the UFP was not attainable, its continued existence instilled a cost consciousness at the contractor that almost certainly would not otherwise have prevailed.

On the other hand, program office engineers described the UFP as shortsighted, claiming that the design compromises it forced Ryan to make actually increased costs in the long run and that total life-cycle cost would increase as a result. Compromises made in the original air vehicle design with the aim of keeping the UFP down proved to be unwise in the long run.

The engine and sensor suite were necessary to the Global Hawk system. These items were nondevelopmental, and their cost to Ryan thus depended more on market conditions than on basic capability. Because unit costs decline when production volume increases, the volume of their sales outside the Global Hawk program had a direct impact on their cost to the Global Hawk program. This put the ultimate cost of these items out of the control of both Ryan and the program office.

The engine and sensor suites were estimated to have cost Ryan $5.7 million of the original cost estimate of $8.7 million for the entire Global Hawk aircraft (adding a profit of $1.3 million gives the total $10 million UFP). This left a maximum of $3 million directly within Ryan's control, out of which the avionics and airframe structure and systems must be afforded. The air vehicle structure had to be built to withstand flight, so the only place to truly save was in nonflight criti-

cal airframe systems and sensor payload integration hardware. The ramifications of these circumstances are not entirely clear, but we believe that the ACTD configuration aircraft ended up with diminished overall system reliability and maintainability characteristics as a result.

The ISS should provide the imaging capability desired from the system. However, onboard processing and data transmission rates may have been constrained by the UFP requirement. The GHSPO insisted that it did not back off in these capabilities. However, the GHSPO was not afforded the traditional development approach's customary cost-effectiveness design trades to determine the optimal allocation of processing and data transmission capabilities between the air vehicle and ground station. The UFP dictated that the cost of onboard components be minimized. As a result, the overall system might have been more capable at the same overall cost if systemwide cost-effectiveness had dictated what went onboard the air vehicle and what resided in the MCE.

EXPLAINING THE FAILURE TO ATTAIN THE UFP

In the December 1998 GAO report, the HAE UAV program office is cited as viewing the failure to meet the UFP as not constituting a failure on the part of the DoD's HAE efforts. We agree with this assessment. The reasons the program's sole requirement was not met are many, but we see them as falling into three categories:

- **Little or no analytical basis in support of the UFP.** This was the result of a deliberate philosophy of *setting the price* at what was believed the customer was willing to pay rather than at what actual costs would be.
- **Rationalization of the UFP through extremely optimistic and essentially *unrealistic assumptions.*** These unfulfilled assumptions resulted in direct cost increases for components that make up the air vehicles themselves and in direct cost increases for running the manufacturing and engineering organizations executing the program.
- **The unwillingness of government program management to mandate the *cost control philosophy* defined at the program's**

inception. The DARPA program office was unwilling to give up major system capability to meet the UFP requirement.

Setting the Price

Initial cost estimates in most weapon system development efforts are based on rigorous analyses. The cost growth that does occur comes about through the usual inherently optimistic economic and technical assumptions on which program estimates are based; through funding instability; and through the evolution and addition of requirements during the development process.

What was different in the HAE UAV ACTD program was that no serious analysis underlay the UFP. To our knowledge, this number was not connected to Tier II+ or Tier III– desired capabilities in any analytical sense. Instead, we believe that the $10 million UFP was selected because it was judged to be high enough to provide a system with meaningful capability if adhered to, yet at the same time low enough that the Air Force would be willing to pay it. We submit that the DUSD(A&T) believed that the price must be set artificially low or the program would be abandoned even before it began. We further submit that the DUSD(A&T) felt compelled to use this tactic because of the false notion embedded in Air Force culture that UAVs are inherently less complicated to develop and build than manned aircraft with similar capabilities.

The UFP was allowed to be part of the program long after it was known to be unattainable. The former DUSD(A&T) and DARPA director throughout most of DARPA's management of the program believed that if the program could be kept going long enough to get one of the systems flying and providing imagery, the Air Force would see the system's potential and would no longer be as concerned with its price. This is, in effect, what happened.

Unrealistic Assumptions

The UFP closeout briefing given by the GHSPO in March 2000 outlined specific assumptions on which the UFP had been based that did not come to pass (Table 3.3). Many of these unmet assumptions

Table 3.3

Comparison of UFP Original Assumptions with Current Program Realities and Assumptions

Variable[a]	Original Assumptions[b]	Actual and Current Assumptions
Payload mix	10 SAR, 8 EO/IR, 8 survivability suites	2 SAR, 1 EO/IR, no survivability suites
Section 845 OTA	Continued use	No use
Production rates	2, 8, and 10	Production rates of 2, 3, 2, 2, and ?
SBU	Contractor has separate Tier II+ SBU	SBU recombined with parent organization
Parallel sales	HISAR, Citation X, Embraer, and ABIT	None
Production facility	Off-site, low-cost facility (George Air Force Base)	Off-site facility at San Diego and Palmdale
Inflation rates	Fixed inflation at 3 percent per year	OSD inflation indices
Fee	15 percent fee	12.5 percent fee
COTS	Minimal incorporation	More difficult to incorporate

[a]SBU = Strategic business unit; COTS = commercial off-the-shelf equipment.
[b]HISAR = Hughes Integrated SAR.

were not under the control of the DARPA or Air Force program offices. A discussion of each follows.

The original program plan was not adhered to. It called for two aircraft in Phase II, eight aircraft in Phase III, and the ten aircraft applicable to the UFP in Phase IV. The actual production plan built the intended two aircraft in Phase II but only three in Phase III, followed by two more in Phase IIC. As of early 2001, only these seven aircraft had been committed to. It is not known when air vehicles 11–20 will be built, but what is known is that they will almost certainly not be built in one lot at the production rate originally envisioned. Current plans have air vehicles 11–20 built over a number of years, making their rate of production a fraction of that originally envisioned.

Air vehicles 11–20 will not be built under an OT contractual arrangement as had originally been assumed. All activity in the Global

Hawk program put on contract after June 30, 2000, was required to comply with conventional acquisition processes. Loss of the OTA increases costs across the board as compliance with the Armed Services Procurement Act, the Competition in Contracting Act (CICA), the Federal Acquisition Regulations (FARs), the Defense Federal Acquisition Regulations (DFARs), and all procurement system regulations are applied to the program. Existing regulations, military specifications, and DoD directives and instructions that have not already been invoked by the program office are now required as well, further adding cost.

Another assumption essential to meeting the UFP was the contractor's program execution under a separate strategic business unit (SBU). The SBU would be financially segregated from its corporate parent and not subject to corporate- and division-wide overhead functions that contribute to normal overhead rates. While an SBU was successfully used by Ryan during the early years of the ACTD, future program plans envision no SBU for the Global Hawk program, and in fact none is warranted given that the OTA has been revoked.

Related to the SBU arrangement was the assumption that Global Hawk would be manufactured at an "off-site facility" to make possible so-called low cost production. It was assumed that this site would be George Air Force Base. Instead, current and future Global Hawk production is taking place at Northrop Grumman's facility in Palmdale, California. This is the same facility where the B-2 bomber was built and is being upgraded. There are no grounds on which to describe the Palmdale facility as low cost.

To meet the UFP, parallel sales of key air vehicle and sensor suite components were also assumed. This meant that Global Hawk components would be used in other civilian or military systems. It was assumed that the increased production volume that would result from multiple customers would reduce the components' unit cost. This assumption included customers for two important components that collectively made up 40 percent of the UFP: the engine and the SAR. The former substantially met its UFP goal, but the latter fell far short of projected sales and therefore contributed significantly to the increased estimates of the UFP.

In one area, the DARPA program office directed a major design change that increased the UFP: the redesign of the wing. Although the necessity for this redesign was disputed, Ryan ultimately succumbed to pressure from the program office and both designed and produced the stronger wing. According to GAO, this change alone added $1.9 million to the UFP.[2]

Cost Control Philosophy

To ensure that they would be able to meet the UFP requirement, contractors were officially given the right—indeed, the responsibility—to trade off performance to meet the UFP. In the early stages of the program, however, when the decisions that most affected the system's cost were made, the DARPA program office did not allow Ryan control of the design to the extent necessary to meet the UFP requirement. The contractor stated that the government had to be "periodically reminded" that Ryan was supposed to be in charge. Ryan also stated that it had an ongoing dispute with the DARPA program office regarding the capability required to provide military utility. This dispute was fueled by the definitional ambiguity surrounding the concept of military utility. According to Ryan, when asked to define military utility for the Global Hawk system, a visiting general officer stated, "Don't ask me to define it—I'll know it when I see it."

The need for the EO/IR suite onboard the UAV was the source of the largest disagreement. In the 1997 time frame, Ryan asserted that this payload should be omitted in order to meet the UFP. Ryan believed that the user would find the system acceptable without this capability. The DARPA program office, however, was steadfast in its opposition to dropping the EO/IR payload; hence, Ryan felt it had no choice but to keep the EO/IR regardless of its implications for the UFP requirement. As a result of the destruction of Global Hawk air vehicle 2 and the taxi accident involving Global Hawk air vehicle 3, no useful imagery was produced by the EO/IR payload throughout the entirety of the D&E phase or at any time during the ACTD. Despite the sys-

[2]See U.S. General Accounting Office, *Unmanned Aerial Vehicles: Progress Toward Meeting High Altitude Endurance Aircraft Price Goals*, December 1998.

tem's failure to demonstrate this major capability, Global Hawk received a favorable MUA.

One DARPA official admitted that very early on—in fact, by the time of Phase II award to Ryan in April 1995—the willingness to trade performance to lower cost was in question. We were told that the government's commitment to the UFP above all other concerns was disregarded almost immediately after the program began. All players knew from the beginning that both sensor suite payloads were "requirements" and that the acquisition-strategy premise of commitment to the UFP above all else was violated within the first six months of the program. The idea that the government would be willing to accept significantly diminished capability to meet the UFP—or for any other reason—ultimately proved to be false.

POST-UFP

Beginning in early 2000 and shortly after the UFP was abandoned, the Air Force program office began to rectify the undesirable compromises the UFP had engendered in air vehicle system architecture and integration infrastructure. The eighth air vehicle will have what is known as a Block 5 configuration. This air vehicle will be the first to be built with a completely new system architecture and integration infrastructure—one that will greatly improve system reliability and maintainability, and hence operational suitability.

With the abandonment of the UFP in early 2000 and the emergence of Global Hawk from its unique ACTD environment, the program no longer enjoys the protection of relatively stable requirements (or "desirements" given the official absence of the aforementioned during the ACTD). This allowed for the consideration of Global Hawk as a replacement for the U-2. This consideration represents the classic UAV scenario wherein the program's costs spiral out of control as a result of the imposition of dramatically more demanding requirements. Global Hawk unit price estimates of up to four times the UFP are now openly discussed under the assumption that the system will evolve to a "U-2-type" capability. This concept involves the addition of more sophisticated sensors, or a SIGINT capability, to the existing airframe.

Chapter Four

COMPARISON TO OTHER SYSTEMS

In this chapter, the Global Hawk and DarkStar systems are characterized in efforts to provide an understanding of the complexity of each HAE UAV system in relation to other development efforts. This perspective is then combined with the understanding—as established in Chapter Two—of what was accomplished during the ACTD in each HAE UAV program, together with its associated cost and schedule.

The best description of what occurred in the HAE UAV ACTD program is that the effort constituted something more than a traditional dem/val but less than an EMD program. We view the ACTD as containing a prototype or dem/val phase, plus selected portions of a typical EMD program, plus the rough equivalent of IOT&E.[1]

CHARACTERIZING THE HAE UAV SYSTEMS

The Global Hawk system consists of multiple segments: an air vehicle, an engine, two sensor payloads, a sophisticated communications suite, and two ground segment components—one for launch and recovery (the LRE) and the other (the MCE) for in-flight air vehicle and sensor control as well as for image processing and dissemination to multiple users in multiple military services. Although many of the key components of each of these segments consisted of commercial or government off-the-shelf equipment, the air vehicle itself was de-

[1]The Global Hawk D&E activity and traditional IOT&E programs differ in that participation in joint training exercises is usually not part of IOT&E. The common thread is testing from an operational perspective.

veloped from scratch. The basic planform or shape of Global Hawk is not revolutionary, and thus the air vehicle's design did not pose a particularly difficult challenge. Instead, the real challenge in the Global Hawk ACTD lay in integrating the payload and aircraft; creating a mission planning capability for a system with a 30-plus-hour sortie duration; and developing the connectivity required to get imagery from the aircraft to multiple users via the MCE. These were highly complex system engineering endeavors that required sophisticated software development tasks.

The DarkStar system also consisted of multiple segments: an air vehicle, an engine, two sensor payloads, and ground stations that provided functions similar to those of Global Hawk. In the DarkStar program, the air vehicle's planform was driven by the expectation that it would be multiaspect LO and that it would perform HAE missions. Its development thus posed a serious technological challenge—some believe vastly more so than that embodied in the Global Hawk program. DarkStar also faced system engineering and software development challenges similar to those seen in Global Hawk. Making the DarkStar effort even more daunting was a decision made 18 months into the program to create the CGS by integrating DarkStar functionality into the ground segment of Global Hawk.

PERSPECTIVE TO OTHER DEVELOPMENT EFFORTS

Most MDAP-size aircraft development efforts handle only one or two of the segments that are part of the Global Hawk and DarkStar systems. Air vehicle development programs do not usually include the development of any type of ground station or payload; advanced radar, targeting, and weapon control systems are more frequently developed in separate programs managed elsewhere. For ISR aircraft, sensor payloads often originate from the intelligence community. Some payloads are developed independent of the airborne platform that will carry them. The development of ISR payloads is usually not part of the airborne platform's overall development effort.

The two basic development efforts in the HAE UAV ACTD program were as difficult as those of most major defense systems. The HAE UAV efforts did not simply involve the building of a glorified model airplane or drone, as some who view UAVs as "low tech" compared

to manned aircraft might imagine. To the contrary, the Global Hawk and DarkStar programs were in many respects more complex and challenging than typical manned aircraft development efforts.

Given the complexity of these systems, we compare both HAE UAV systems to manned aircraft developments that, at a minimum, created an all-new air vehicle design. We do not compare the HAE UAV systems to historical UAV development efforts, as we find no unclassified or declassified UAV program with both sufficient available data and sufficient complexity and technological challenge to justify such a comparison.

COMPARISON APPROACH

Development activity through the end of the ACTD and into follow-on development efforts was examined in two segments: the early portion embodied in the ACTD's Phase II, which involved the design and build of the first two air vehicles, and the remainder of the ACTD along with proposed follow-on development activity. The former applies to both the Global Hawk and DarkStar programs; the latter applies only to Global Hawk. Analysis of DarkStar beyond Phase II was not warranted because its Phase IIB—the building of follow-on aircraft—was not completed.

Phase II Comparison Programs

Figure 4.1 compares the costs of the two HAE UAV Phase II efforts to those of some of the major dem/val, prototype, and technology demonstration programs of the past 30 years.[2] The systems in Figure 4.1 represent experimental, fighter, attack,[3] cargo, and reconnaissance aircraft. A roughly similar set of basic activities is found in all

[2]The F-22 dem/val program is not shown, as its cost and complexity dwarf those of typical military aircraft dem/val programs. Its cost was more than $2 billion in then-year dollars (when prime and subcontractor investments are included) for the YF-22 and YF-23.

[3]The Have Blue technology demonstration program informed the development of the F-117, which is essentially an attack aircraft.

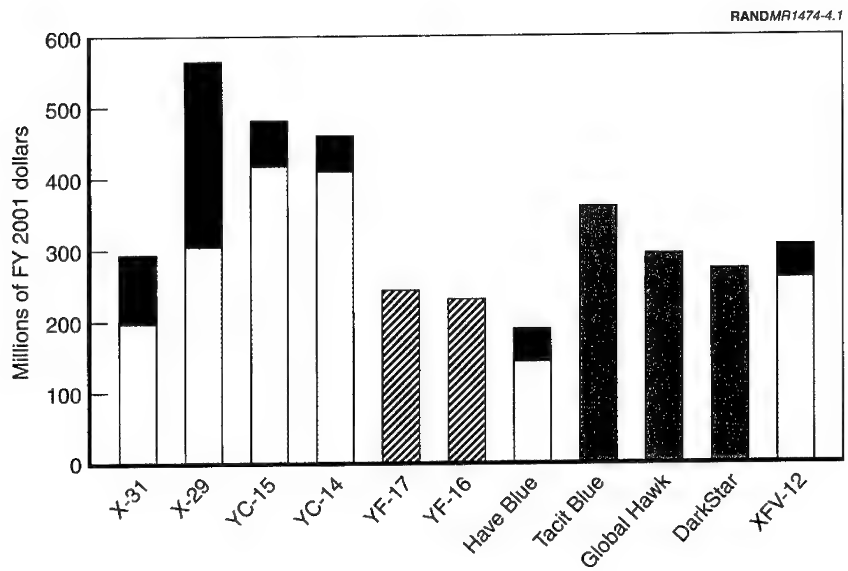

Figure 4.1—Program Comparison: Equivalents to Phase II of the HAE UAV ACTD

of these programs regardless of whether the air vehicle was intended to evolve into an operational weapon system.[4]

For the programs showing two segments to their cost bar, the lower segment represents the program's cost excluding flight test activity, which is accounted for in the upper segment. The OT contractual arrangements in the Global Hawk and DarkStar programs made it difficult to break out flight test costs from those of other activities during Phase II; thus, a single-segment bar is shown for the total cost of the phase. Tacit Blue data were available only in aggregate; hence the single bar. The costs of flight testing in the Lightweight Fighter (LWF) program—that is, the YF-16 and YF-17—did not come out of these programs' budgets and were not separately accounted for. As a

[4]Dem/val and prototype programs often lead to follow-on development efforts, whereas technology demonstration programs are not intended to have direct descendants.

result, these flight test costs are not available in the historical record and are not included in Figure 4.1.[5]

Total expenditures in the programs, escalated to FY 2001 dollars, range from a low of less than $200 million to a high of more than $500 million. The average costs for the design-and-build portion and for the flight test portion of the historical programs for which such costs can be determined are $275 million and $92 million, respectively.[6] By our calculations, Global Hawk Phase II cost $238 million in payments to contractors plus allocated government costs of roughly $40 million.[7] DarkStar Phase II cost $220 million in payments to contractors plus allocated government costs of some $37 million.[8] Converted to FY 2001 dollars, the Global Hawk and DarkStar totals come to $295 million and $273 million, respectively.[9]

Each program shown in Figure 4.1 accomplished a unique set of activities. To put each in perspective in relation to the HAE UAV efforts, these programs are briefly characterized below.

- **X-31.** This DARPA/U.S. Navy technology demonstration program was a cooperative U.S.-German effort.[10] Two aircraft were built and flown to study enhanced fighter maneuverability. The aircraft had minimal avionics and no weapon systems. The design made extensive use of existing airframe systems from other fighter aircraft; the airframe structure was essentially new. The

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[5]See Lieutenant Colonel Morris R. Betry, USAFR, "The History of Technology Viability, Technology Demonstrator, and Operational Concept Prototype Program Costs," July 1994.

[6]The average for the design-and-build portion is calculated from these costs in the X-31, X-29, YC-15, YC-14, YF-17, YF-16, Have Blue, and XFV-12 programs. The average for the flight test portion is calculated from this cost in the X-31, X-29, YC-15, YC-14, Have Blue, and XFV-12 programs.

[7]See Table B.1 for a detailed breakout of Global Hawk Phase II payments to contractors.

[8]See Table B.2 for a detailed breakout of DarkStar Phase II payments to contractors.

[9]As shown in Table D.2, as of January 1999 total government costs during the ACTD were estimated at $138 million. Global Hawk Phase II accounted for 29 percent of all payments to contractors in the ACTD; thus, that percentage of government costs is allocated to the effort. For DarkStar, the figure is 27 percent.

[10]See *Jane's All the World's Aircraft, 1995–1996,* Coulsdon, UK: Jane's Information Group Ltd., 1995; and interview with Frank Leo, cost analyst at Rockwell North American Aircraft, 1993.

aircraft were designed and built in the late 1980s and were flown more than 400 times between 1990 and 1993,[11] with the U.S. Air Force and NASA conducting the latter portion of flight testing. The program's challenge lay in designing a new and innovative airframe that incorporated thrust vectoring and integrated control systems.

- **X-29.** This DARPA technology demonstration aircraft was built to study flight characteristics of a forward swept-wing air vehicle planform.[12] The aircraft had minimal avionics and no weapons systems or payload other than instrumentation. The design made extensive use of existing airframe structures and systems from other fighter aircraft. Two air vehicles were built in the early 1980s. The first was flown 254 times from 1984 through 1988; the second was flown 173 times from 1989 through 1991. The program's challenge lay in making the unique planform flyable.
- **YC-15.** This was one of two U.S. Air Force prototype fly-off development efforts in the Advanced Medium Short Takeoff and Landing Transport (AMST) program.[13] This prototype was the predecessor to the C-17. Wherever possible, the design used existing airframe structures and systems from commercial and military aircraft. The program took place from 1972 to 1977, with two aircraft built and flown. Flight testing took place in two phases over 20 months in the mid-1970s and included 341 flights that accumulated 679 flight hours. The program's challenge was meeting the short takeoff and landing requirement. This was attained through use of a high-lift blown flap system.
- **YC-14.** This was the other U.S. Air Force prototype fly-off development effort of the AMST program.[14] Its program structure was

[11]Flight testing continued under the Joint Advanced Strike Technology (JAST) program until one aircraft crashed in January 1995. The JAST effort is not included in the program estimate shown in Figure 4.1.

[12]Interview with Bob McGuckin, former X-29 program manager, 1993. See also *Jane's All the World's Aircraft, 1989–1990,* Coulsdon, UK: Jane's Information Group Ltd., 1989.

[13]See *Jane's All the World's Aircraft, 1978–1979,* Coulsdon, UK: Jane's Information Group Ltd., 1978.

[14]Ibid.

similar to that of its competitor. The program took place within the same time frame and built and flew two aircraft in a similar flight test program. Flight testing accumulated more than 600 flight hours between August 1976 and August 1978. This prototype met the short takeoff and landing requirement using its "upper surface blowing" concept.

- **YF-17.** This was one of two DARPA/U.S. Air Force prototype fly-off development efforts in the LWF program. This prototype was the predecessor to the F/A-18.[15] The rules governing the program's execution were similar to the OT construct of the HAE UAV program. Two aircraft were designed and built beginning in 1972. Flight testing consisted of 268 flights that accumulated 324 flight hours and took place in the last seven months of 1974. Most of the technologies in the LWF prototypes had been previously tested but had not been brought together; this was the challenge in the LWF program.

- **YF-16.** This was the other DARPA/U.S. Air Force prototype fly-off development effort in the LWF program.[16] This prototype was the predecessor to the F-16. It benefited from the same OT-like program management style as that of the YF-17 program. Two aircraft were designed and built beginning in 1972. Flight testing took place over ten months in 1974 and consisted of 320 flights with 450 total flight hours. This prototype shared the LWF program challenge of integrating existing advanced technologies applicable to air combat.

- **Have Blue.** This highly classified DARPA/U.S. Air Force technology demonstrator was the first aircraft designed specifically to be LO.[17] It was the predecessor to the F-117 stealth fighter. Two subscale air vehicles were built and flown 88 times over the 18-month flight test program, which concluded when both aircraft were destroyed in crashes. The air vehicles were described by

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[15]See *Jane's All the World's Aircraft, 1975–1976*, Coulsdon, UK: Jane's Information Group Ltd., 1975.

[16]Ibid.

[17]See Giles K. Smith, Hyman L. Shulman, and Robert S. Leonard, *Application of F-117 Acquisition Strategy to Other Programs in the New Acquisition Environment*, MR-749-AF, Santa Monica: RAND, 1996.

one program participant as "barely flyable." The program took place in the mid- to late 1970s and lasted little more than three years. The effort's technological challenge was to prove that the planform was both flyable and LO.

- **Tacit Blue.** This highly classified DARPA/U.S. Air Force prototype was built as a stealthy, low-speed, long-endurance surveillance aircraft.[18] This technology demonstrator carried an imaging SAR and was capable of transmitting imagery to a ground station. The design made extensive use of existing airframe systems from other fighter aircraft. The effort began in 1978. Only one complete air vehicle was built and flown; a second airframe was substantially but not completely constructed as a backup. The aircraft was described at the time as "the most unstable aircraft man had ever flown." The completed aircraft flew 135 times for a total of 250 flying hours from 1982 through 1984. The primary program challenge lay in making the multiaspect LO air vehicle planform—the first to use curvilinear surfaces—flyable.
- **XFV-12.** This U.S. Navy technology demonstrator was to build a supersonic vertical/short takeoff and landing (VSTOL) aircraft employing a thrust-augmented wing for lift.[19] The air vehicle had no onboard weapon systems. The aircraft used the forward fuselage and undercarriage from the A-4 Skyhawk and the wing box and air intakes from the F-4 Phantom. The effort took place in the mid-1970s and was canceled after the projected schedule had stretched from three years to ten years and estimated costs had more than doubled. The program initially sought to build two aircraft but was scaled back to one. Its challenge was to demonstrate supersonic flight with VSTOL capability. The aircraft never achieved free flight. It is not known how much it

[18]See "Air Force Unveils Stealth Technology Demonstrator," Air Force press release 01-04-96, April 30, 1996; "Secret Flights in 1980s Tested Stealth Recon," *Aviation Week & Space Technology*, May 6, 1996, pp. 20–21; and "The (Tacit) Blue Whale," *Air Force Magazine*, August 1996, pp. 51–55.

[19]See Betry, "The History of Technology Viability, Technology Demonstrator, and Operational Concept Prototype Program Costs," July 1994, and "V/STOL Technology Advances Expected," *Aviation Week & Space Technology*, January 31, 1977.

would ultimately have cost to achieve the program's original goals.

DarkStar Phase II Comparison

Given what we know about the above-described efforts and the accomplishments of the DarkStar program, we find that DarkStar best compares to the Have Blue and Tacit Blue technology demonstration programs. Table 4.1 shows both the similarities and differences of the three programs. Point-by-point comparisons are given below.

All three programs involved the design and build of two examples of an all-new LO airframe. As the Tacit Blue and DarkStar aircraft were to perform ISR missions, their planforms were multiaspect LO. The Tacit Blue program ultimately flew only one of the airframes; the other was intended to fly only if the first was lost. In the Have Blue program, it is not clear if both airframes were planned to be flyable at the program's inception, but both were ultimately flown. In the DarkStar program, only one airframe was intended to fly, but the second was made flyable following the crash of the first.

All three technology demonstrators were described as aerodynamically unstable and were not flown in adverse weather conditions. All

Table 4.1

DarkStar Comparative Programs

Variable	DarkStar	Have Blue	Tacit Blue
All-new airframe design	Yes	Yes	Yes
LO planform	Multiaspect	Yes	Multiaspect
Two airframes: one flyable/one backup	Yes	Probable	Yes
Aerodynamic stability	Unstable	Unstable	Unstable
Performance	Minimal	Minimal	Minimal
Sortie endurance	Long	Short	Long
Sensor payload	Yes	No	Yes
Flight test: hours/flights	7/6	Unknown/88	250/135
Development approach	OT	OT-like	OT-like
Program length in years	4.5	3–4	7+
Cost (millions of FY 2001 dollars)	$273	$186	$360

three had relatively low performance with barely enough power to be flyable. DarkStar and Tacit Blue were designed to provide SAR imagery and to fly for long periods. Tacit Blue actually carried its payload and took imagery, while DarkStar's payloads took imagery only from a separate test-bed aircraft. Have Blue was much less capable, with no payload and minimal sortie duration.

Tacit Blue had a fairly extensive flight test program. That of Have Blue was substantial as well, while DarkStar's was minimal. All three programs enjoyed special status, allowing them to be managed under OT-type rules. Total program length was shortest in the Have Blue program, somewhat longer in DarkStar, and much longer in Tacit Blue thanks to three years of flight testing.

The total cost to the government of DarkStar Phase II lay halfway between the costs of the two comparative programs. The shorter Have Blue program, which created a technology demonstrator of arguably less capability than DarkStar, cost some $87 million (in FY 2001 dollars) less than DarkStar. The longer Tacit Blue program, which created what is described as one of the most successful technology demonstration programs in Air Force history and was arguably more capable than DarkStar, cost some $87 million (in FY 2001 dollars) more than DarkStar. We believe that the final cost of DarkStar Phase II was roughly what one would expect given what was accomplished and the historical experience of similar programs.

Global Hawk Phase II Comparison

It is more difficult to find comparisons for Global Hawk Phase II. The only aircraft built with even roughly similar characteristics were the following:

- The U-2, initially designed in the mid-1950s. No data are available regarding the design and test of its first two air vehicles.
- The two competitors in the Compass Cope program, designed in the early 1970s. Two pairs of HAE UAVs were built. Only airframes were developed; the program included no payload development or system integration efforts.
- The Condor prototype built and flown in the 1980s. This remotely piloted vehicle was a very low speed, piston-powered,

200-foot-wingspan technology demonstrator. It flew just eight times, carrying instrumentation only.[20]

We find none of these systems suitable for our comparison. Of the programs shown in Figure 4.1, we find that Global Hawk Phase II best compares to the YF-16 and YF-17 prototype programs. Table 4.2 shows both the similarities and differences of the Global Hawk and LWF programs. Point-by-point comparisons are given below.

All three programs involved the design and build of all-new, low-risk planform airframes. The primary challenge in all three programs lay in the integration of mature or maturing technologies. All three programs built two flyable airframes, as intended from each program's inception. Two of the three air vehicles were aerodynamically stable,[21] and all three were flown during test, as would be required to

Table 4.2

Global Hawk Comparative Programs

Variable	Global Hawk	YF-16	YF-17
All-new airframe design	Yes	Yes	Yes
Planform	Low risk	Low risk	Low risk
Technological challenge	Integration	Integration	Integration
Two airframes: both flyable	Yes	Yes	Yes
Aerodynamic stability	Stable	Relaxed	Stable
Performance	Adequate	Excellent	Excellent
Sortie endurance	Long	Adequate	Adequate
Payload	Sensors	Weapons	Weapons
Flight test (hours/flights)	158/21	450/320	324/268
Development approach	OT	OT-like	OT-like
Program length in years	4.5	2.5	2.5
Cost (millions of FY 2001 dollars)	$295	$233 excluding flight test	$242 excluding flight test

[20]See "Boeing Condor Raises UAV Performance Levels," *Aviation Week & Space Technology*, April 23, 1990, pp. 36–38.

[21]The exception was the YF-16 and subsequent F-16A, which had negative static stability throughout much of their subsonic flight envelope.

accomplish their intended mission. What is meant here is that excessive caution was neither required nor exercised during flight testing. All three had the performance required to attain their intended mission. The LWF prototypes had ranges representative of a production fighter aircraft, while Global Hawk had sufficient endurance and altitude for its intended mission. All three carried their intended payloads—weapons on the LWF prototypes and sensors in Global Hawk.

Both LWF prototype programs had short but vigorous flight test programs lasting ten and seven months for the YF-16 and YF-17, respectively. Global Hawk's engineering flight test was less extensive but took place over some 17 months. All three programs enjoyed special status, allowing them to be managed under OT-type rules. The Global Hawk Phase II program took longer than the LWF prototypes to attain first flight and was two years longer overall than the LWF prototype programs.

The total cost to the government of Global Hawk Phase II was some 20 percent to 25 percent more than the inflation-adjusted figures recorded for the LWF prototype programs. When estimates for contractor and subcontractor investment, government-provided aircraft engines, and other government-furnished equipment (GFE) are included in the LWF cost, the figures are closely comparable to those from Global Hawk Phase II.

However, one major cost is excluded from the LWF program figure: flight test costs. These costs were not available for the LWF prototype efforts and thus are not included in their costs. The Global Hawk figure includes almost all flight test costs attributable to Phase II. The program paid for petroleum, oil, and lubricants (POL),[22] apron space, and range time throughout the phase. The only minor cost not included was the assistance provided at Edwards Air Force Base by the 31st TES. This assistance—provided to the program free of charge—did not become substantial until after Phase II was completed.

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[22]POL is a standard Air Force maintenance term that includes all fluids customarily consumed during flight operations.

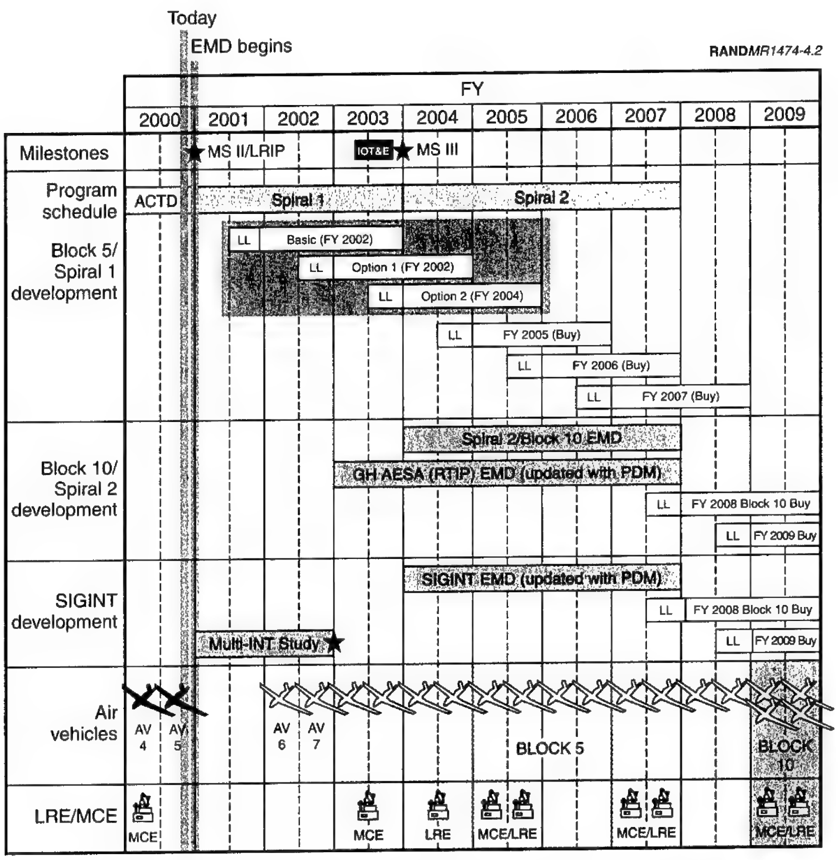
We believe that the costs of 17 months of flight testing that were borne by the Global Hawk program during Phase II probably make up the difference between its cost and those recorded for the YF-16 and YF-17 prototype programs. Therefore, we believe that the ultimate cost of Global Hawk Phase II was roughly the same as that for the LWF prototypes. This is a favorable outcome given that conventional wisdom views the LWF prototype program as one of the most successful prototype programs in Air Force history.

Global Hawk Further Development Comparison

The six sequential (with some overlap) development efforts beyond Phase II are in aggregate considered to be the Global Hawk program's equivalent EMD. These efforts are Phase IIB and Phase III as part of the ACTD, Phase IIC and pre-EMD as bridge activities between the ACTD and EMD, and the planned Spiral 1 and Spiral 2 developmental phases. Defining the equivalent EMD makes possible a cost comparison between Global Hawk and other aircraft EMD programs.

As of December 2000, the Global Hawk–equivalent EMD was planned to span a full ten years, from the beginning of the ACTD's Phase IIB in August 1997 through the planned end of Spiral 2 in FY 2007. Any additional development beyond Spiral 2 is not considered part of the system's initial development effort. We are able to draw this distinction because the Spiral 2 effort is intended to yield a fully ORD-compliant configuration—the Block 10. Any follow-on development efforts would go beyond what is expected from the fully developed system, which is to say that they are not part of the original development effort. The schedule for Spirals 1 and 2 as of December 2000 is shown in Figure 4.2.

There are no procurement dollars in the first four phases of the equivalent EMD; thus, their entire cost is included in our estimate. In the final two phases, Spirals 1 and 2, only those dollars specified for research, development, test, and evaluation (RDT&E) are included in our total for the equivalent EMD. Some $600 million in Global Hawk program funding for procurement and operations and maintenance for FY 2001 through FY 2007 are excluded. These funds are intended to purchase twelve Block 5 air vehicles; to provide long-



SOURCE: Global Hawk System Program Overview briefing, Aeronautical Systems Center/Reconnaissance Air Vehicle (ASC/RAV) directorate, December 2000.

Figure 4.2—Spirals 1 and 2 Plan at ACTD Completion

lead funding for the first two Block 10 air vehicles; and to operate the Global Hawk fleet from FY 2002 through FY 2007.

The costs of the two ACTD phases, Phases IIB and III, can be fairly well estimated, as they are substantially completed. The costs of the two bridge phases, Phase IIC and pre-EMD, are based on the initial contract values agreed on with Ryan in June 2000 plus a factor to cover government costs. Their actual costs might grow, as they are

only at the beginning of their execution. The costs of Spiral 1 and Spiral 2 RDT&E efforts can be estimated only roughly. They were derived by allocating the remaining Global Hawk RDT&E funding for FY 2001 through FY 2007 as shown in the FY 2002 budget estimate submission (BES) position as of November 2000.

How much funding materializes for Spiral 1 and Spiral 2 RDT&E and what is actually accomplished in these phases remain to be seen. As shown in Table 4.3, almost half of the funding for the ten-year equivalent EMD is in Spiral 2, which is not expected to begin until FY 2004. This puts almost half of the equivalent EMD funding in the out years of the Future Years Defense Plan (FYDP). Out-year FYDP funding is questionable in any acquisition program; thus, that for Global Hawk is highly uncertain.

Table 4.3 shows total estimated funding of $1100 million in FY 2001 dollars for the equivalent EMD. Given the high level of uncertainty in this figure, we believe it appropriate to define a broad range for our estimate of the equivalent EMD. If defense budgets become tight and a less capable system is settled on, Spiral 2 may never come to pass. As a result, what is ultimately spent on the equivalent EMD

Table 4.3

Equivalent EMD in Global Hawk

Activity/Phase	Activity Time Frame (FY)	Funding (millions of FY 2001 dollars)
ACTD, Phase IIB	1997–1999	162
ACTD, Phase III	1999–2001	130
Bridge, Phase IIC	2000–2003	89
Bridge, Pre-EMD	2000–2003	135
EMD, Spiral 1	2001–2003	58
EMD, Spiral 2	2004–2007	526
"Equivalent EMD," sum of all	1997–2007	1100

SOURCES: Phases IIB and III are from Tables B.3 and B.4, respectively, inflation adjusted to FY 2001 dollars plus a 16.7 percent factor for government costs as derived from Table D.2. Phase IIC is from the values of Ryan CLINs 20 and RayES CLIN 17, inflation adjusted to FY 2001 dollars plus the same factor for government costs. Pre-EMD is from the value of Ryan CLIN 22, inflation adjusted to FY 2001 dollars—plus the same factor for government costs. Spirals 1 and 2 are derived from the FY 2002 BES as shown in the program office's November 2000 "quad chart," subtracting out the appropriate budget portions for Phase IIC and the pre-EMD.

could be as much as $500 million less than our estimate. On the other hand, if the funding environment improves in the out years and the program experiences typical EMD cost and schedule growth, Spiral 2 might stretch two or three additional years, and as much as $500 million more might ultimately be spent to develop an ORD-compliant system.

Given the possibility of these two extremes, we expect that somewhere between $600 million and $1600 million will be spent on the phases that in aggregate make up Global Hawk's equivalent EMD.

Now that Global Hawk's equivalent EMD has been defined and its cost range has been set, we outline three historical EMD programs for comparison. The first two are the EMD programs that came out of the LWF programs—those for the F-16 and F/A-18. We view these two EMD programs as defining the opposite ends of what a Global Hawk–equivalent EMD might be expected to cost. Our third comparative program is the F-117 EMD. On its face, it appears peculiar to compare the conventionally configured HAE UAV to an LO-configured attack aircraft. However, because of similarities in program execution philosophies and structures, the F-117 EMD is in many ways the best comparison for the accumulated six phases that make up the equivalent EMD for Global Hawk.

The YF-16 program was immediately followed by the F-16 EMD program. This program, which was very short and inexpensive by historical standards, is often cited as the model EMD program. The F-16 EMD made extensive use of experience from the YF-16 program, simply evolving the LWF prototype into a production version. It developed the new fighter with a strong emphasis on low cost and getting into production as soon as possible. It represents a very low cost EMD, perhaps on the order of what might be expected for the Global Hawk–equivalent EMD under the assumption that what was learned in the ACTD is fully leveraged. Inflation adjusted to FY 2001 dollars, the F-16 EMD cost some $2.16 billion.

The YF-17 program was followed by the F-18 EMD program. The Navy found the Air Force's twin-jet prototype so promising that it used that prototype as a starting point from which to design and build its next aircraft carrier–capable fighter. The F-18, which evolved into the F/A-18 during EMD, took a more typical approach to

EMD: The predecessor prototype was merely a concept from which to start anew. This EMD program represents perhaps the upper bound of cost for the Global Hawk's–equivalent EMD, based on the assumption that the Air Force decides to build a "bigger and better" Global Hawk. This would be a system not directly evolved from the Global Hawk's ACTD configuration. Inflation adjusted to FY 2001 dollars, the F/A-18 EMD cost some $4.81 billion.

The F-117 EMD and Global Hawk–equivalent EMD efforts share a number of important characteristics.[23] The programs had highly concurrent acquisition phases. The F-117 EMD program began even before the completion of its predecessor technology demonstration program, Have Blue. This is similar to Global Hawk Phase IIB, as it began even before the end of Phase II in the ACTD. In both the F-117 EMD and Global Hawk–equivalent EMD programs, five aircraft that are appropriately described as EMD aircraft were or will be built. In the F-117 program, these were specified as such; in the Global Hawk program, three were built in Phase IIB and two more in Phase IIC.

The production of F-117 aircraft was committed to even before the first flight of an EMD-configured aircraft. For Global Hawk, Block 5 production aircraft are planned to be built during Spirals 1 and 2, which make up the majority of the equivalent EMD's funding and time line. The F-117 EMD program had two phases of roughly similar length and resource expenditure; the first was prior to manufacture of production aircraft, and the second was concurrent with production. There are six planned phases to Global Hawk's equivalent EMD, but the same basic concurrence of production during the latter half of development is anticipated.

Both programs prepared for small but lengthy production runs at low rates. The F-117 program initially envisioned a production run of just 20 aircraft, and thus very little investment was made in production tooling and process improvements. Much the same can be said of the Global Hawk program. In both programs, the aircraft were essentially hand built. The highest production rate attained in the F-117 program was eight per year; the highest rate anticipated for

[23] Much of the F-117 acquisition process information in this section is taken from Smith, Shulman, and Leonard, *Application of F-117 Acquisition Strategy to Other Programs in the New Acquisition Environment*, 1996.

Global Hawk is six per year. Total production in the F-117 program grew to 59 aircraft over nine years. The envisioned Global Hawk force size is similar but will be built over an even longer time period.

System specification was handled similarly in the two programs. The development strategy in the F-117 EMD was to set an absolute minimum number of design and performance specifications as hard requirements and to leave the remainder as goals. A similar philosophy has dominated the Global Hawk development effort thus far. Whether this philosophy can be continued through Spiral 2 remains to be seen.

Military standards, specifications, and regulations were also handled similarly in the two programs. The F-117 EMD program was directed to comply with the intent of applicable military specification, standards, and regulations but was allowed to adapt them appropriately. In the Global Hawk program, even less attention is paid to these instruments in the first four phases of the equivalent EMD. It appears that they will be fully applicable in Spirals 1 and 2.

Both programs have also made extensive use of proven components and subsystems. The F-117 borrowed the GE F404 engine and cockpit head-up display from the F/A-18 program, the inertial navigation system of the B-52, many elements of the F-16 flight control system, and other components. The Global Hawk's use of proven components and subsystems was even more extensive and included the engine, the SAR and EO/IR sensors, and most components in the airframe systems.

Inflation adjusted to FY 2001 dollars, the F-117 EMD cost some $3.16 billion. This figure is $1 billion more than what was spent in the F-16 EMD and $1.65 billion less than what was spent in the F/A-18 EMD. Comparing the F-117 EMD with the Global Hawk–equivalent EMD shows the former to be two to five times the latter.

Complete Development Process Comparison

Figure 4.3 shows the total development costs of our three comparative programs and the low, medium, and high estimates for Global Hawk. For the F-117, the costs of the Have Blue technology demonstration program and the aggregate costs of the two phases of F-117

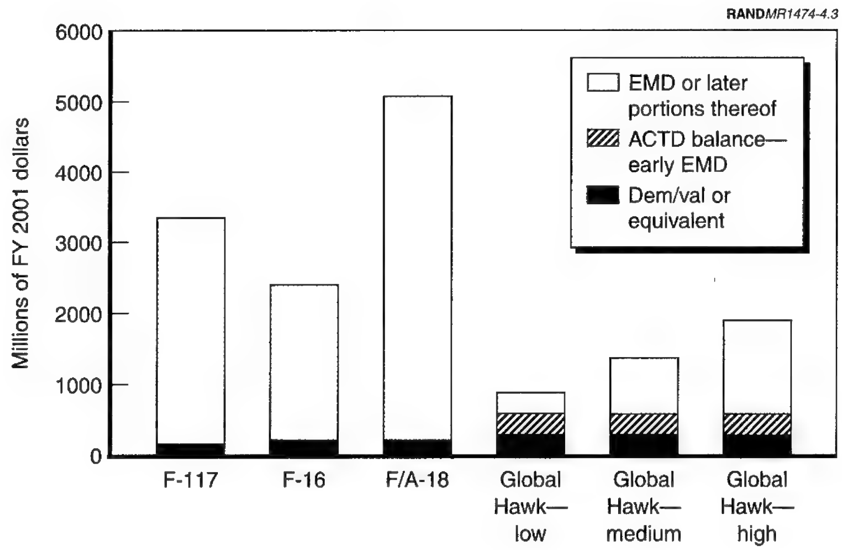


Figure 4.3—Total Developmental Funding Comparison

EMD are shown in the two segments of its cost bar. For the F-16 and F/A-18 programs, the cost of the LWF prototype programs and EMD programs are shown in the two segments of their cost bars. In the Global Hawk cost bar, the cost of the ACTD Phase II is in the bottom segment; the balance of the ACTD, including Phases IIB and III, is in the middle segment; and the projected costs for the two bridge phases plus Spirals 1 and 2 are in the top segment.

The cost of the Global Hawk ACTD's Phases II, IIB, and III is assumed to be fixed, as these efforts are substantially complete. As a result, the two lower segments of the Global Hawk cost are the same in all three cases. Only the top portion of the cost bar is different for the low, medium, and high Global Hawk estimates.

The low estimate for the total development costs is approximately $300 million for Phase II, $300 million total for Phases IIB and III, and $300 million for Phase IIC, pre-EMD, and Spiral 1. As discussed earlier, this case assumes that Spiral 2 is unaffordable and therefore does not materialize. In this minimum program, total development is about $900 million in FY 2001 dollars. The medium estimate is for

the baseline program shown in Figure 4.2, including Spiral 2 at about $500 million. The baseline program's total development is therefore about $1400 million in FY 2001 dollars. The high estimate assumes cost and schedule growth in the remainder of the development process, adding $500 million to the baseline program shown in Figure 4.2. The total development in this worst-case, high estimate is roughly $1900 million.

Even the highest estimate for the Global Hawk development efforts in their entirety is considerably less than what was spent on the F-16. It is only slightly more than half of what was spent on the F-117 and little more than one-third of what was spent on the F/A-18. It thus appears that regardless of which developmental path is taken for Global Hawk, its cost will be considerably less than what one might expect given historical programs of roughly similar technological challenge and system complexity.

Chapter Five

CONCLUSIONS

The HAE UAV ACTD program was in aggregate a success. The program demonstrated the technical feasibility and operational utility of a new system concept. The Tier II+ program to a large extent developed and demonstrated an HAE UAV system capable of affordable, continuous, all-weather, wide-area surveillance in support of military operations. Given follow-on development, Global Hawk will provide ISR information to the warfighter.

The DarkStar effort was terminated fairly early in the overall development process. The DarkStar program accomplished most of what constitutes a traditional technology demonstration program along with some follow-on nonrecurring engineering to improve the system's configuration, as well as the manufacture of some additional developmental assets. The DarkStar program was canceled before a determination of its full operational capabilities could be made.

At the end of the HAE UAV ACTD, Global Hawk was not a fully developed system and did not demonstrate all that the ACTD had called for. However, the system was well along in development. Moreover, it showed the potential to be operationally suitable and militarily useful given a follow-on EMD program involving a small fraction of the time and funding normally required in a traditional EMD program.

ACTD EXECUTION

The HAE UAV programs were designated an ACTD in the first year that Congress authorized this acquisition strategy. Neither the gov-

ernment program management nor the participating contractors had any experience managing within this acquisition strategy. As no program had yet used the strategy, no prior experience could be drawn on. This put program management in the position of interpreting the minimal guidance it was given and literally making up the details of the process as they went along.

DARPA's management of the front end of this program was highly unusual. DARPA, an agency charged with technological innovation, is not in the business of developing new weapon system concepts. Nevertheless, DARPA was expected to complete the design and build of the first two examples of each system and to prove the basic flightworthiness of each. DARPA was then expected to transfer both development efforts to the Air Force. The Air Force, which initially had no stated requirement, budget, or interest in either system, was to complete the ACTD and pave the way for the future development or production of one or both HAE UAV concepts. This plan strikes us as high risk. Its success was therefore a substantial achievement on the part of both DARPA and the Air Force.

In the sense of what was envisioned at the beginning of the program compared to what occurred, the activity content of the ACTD was greatly curtailed while both the cost and schedule of the total effort grew only slightly. What occurred, in effect, was a continuous change in activity content throughout the ACTD in an attempt to stay within the original total cost and schedule constraints defined at its inception. While the ACTD construct largely defined those constraints, other elements of the HAE UAV program's approach enabled management to stay within those bounds while still developing a system with demonstrated military utility. In Global Hawk in particular, the collaborative working relationship established via the use of IPTs allowed for consensus building between the government and contractor; the inherent flexibility of OT provided a mechanism that made implementing change relatively easy; and early user involvement kept the program focused on its primary objective of demonstrating military utility.

The inherently uncertain and risky design, build, and basic testing of the first two aircraft ended up consuming a much larger portion of the allotted budget and calendar time than had been called for in the initial ACTD plan. To stay within these constraints, the planned de-

velopment and testing efforts were greatly curtailed. As a result, not all operational capabilities that the system might be capable of were given sufficient opportunity for demonstration.

When the Air Force took over the management of the ACTD in October 1998, DarkStar lagged far behind the developmental maturity of Global Hawk. Not enough time and resources were left to continue with the two programs through the conclusion of the ACTD. Given these circumstances, and given the apparent technical problems inherent in DarkStar's design, the Air Force decided to cancel DarkStar.

The success of Global Hawk in the D&E phase shows that reducing the activity content to cover increased costs for nonrecurring engineering activities was a wise course of action. The diminished activity content of the ACTD resulted from a serious underestimation of the complexity of the development effort required to create a minimally functional system with the desired HAE UAV capability. The unmanned nature of the air vehicle in some ways made it less challenging and costly to build than a manned air vehicle but in other ways made it more challenging. Had significantly more resources been made available, additional residual assets from the ACTD would be available today, and Global Hawk would be a more fully developed system.

The development efforts of the HAE UAV ACTD were not sufficient to field production-ready systems. The Air Force program office believes that had making the system production-ready by the completion of the ACTD been the overriding priority, this could have been accomplished. However, the overall objective of the acquisition strategy was to provide an enhancement to the warfighter's operational capabilities in a way that was deemed by the users to be worth the cost. Given this overriding objective, the path to success in the ACTD required that the system's military utility be proven via the execution of the D&E program.

Global Hawk is prepared to enter the acquisition process with a greatly abbreviated EMD and concurrent serial production. As a result, the ACTD was sufficient as an acquisition strategy for one of the more desirable post-ACTD paths to be followed. The proposed spiral development represents the logical extension for further acquisition

in this program. Spiral development is essentially what was practiced throughout the ACTD in Phases II, IIB, and III. The spiral development process also accurately describes the phases being used to bridge the ACTD and EMD efforts—that is, Phase IIC and the pre-EMD.

The Unit Flyaway Price

The single program requirement, the UFP, will not be attained in the Global Hawk program and would not have been attainable in the DarkStar program. Yet the HAE UAV program office does not view this failure to meet the UFP as constituting failure on the part of the DoD's HAE efforts. We agree with this assessment.

The reasons the program's sole requirement was not met were as follows:

- **Little or no analytical basis in support of the UFP.** This was the result of a deliberate philosophy of *setting the price* at what was believed the customer was willing to pay rather than at what actual costs would be.
- **Rationalization of the UFP through extremely optimistic and essentially *unrealistic assumptions.*** The result of these assumptions not materializing were direct cost increases for components that make up the air vehicles themselves and direct cost increases of running the manufacturing and engineering organizations executing the program.
- **The unwillingness of government program management to mandate the *cost control philosophy* defined at the program's inception.** The DARPA program office was unwilling to give up major system capability to meet the UFP requirement.

The UFP constraint shaped the system in both positive and negative ways. Its invocation successfully kept additional requirements from being imposed on the program. It put continuous pressure on the contractor to control costs, with both positive and negative results. It could be held over the contractor as paramount and credibly referred to as potentially causing program cancellation if not met. Its continued existence instilled a cost consciousness at the contractor that almost certainly would not otherwise have prevailed.

On the other hand, the UFP forced design compromises that actually increased costs in the long run. Government program engineers believe that total life-cycle costs will increase as a result of the UFP. The setting of a firm price requirement on just one segment of the larger system also created the potential for the nonoptimal allocation of airborne and ground-based capabilities. In addition, it is believed that in the long run, the UFP inhibited systemwide cost control by discouraging investment in more costly basic system design solutions that would more than pay for themselves later, when the system incurs operating and support costs.

In future programs, objectives should be stated as goals, and management must retain the authority to modify the balance among these goals as the program evolves. An acquisition strategy providing for the balancing of and willingness to trade cost, schedule, and system performance will provide the flexibility needed to ensure the best possible overall outcome.

Comparative Success

In many respects, the Global Hawk and DarkStar programs were at least as complex as similar efforts in typical manned aircraft development. Despite this inherent complexity in technology development, integration, and software development, the HAE UAV efforts compare favorably with traditional manned aircraft programs in terms of both cost and schedule. Global Hawk also compares favorably with such programs in terms of performance.

The DarkStar Phase II effort can best be compared to the Have Blue and Tacit Blue programs. The final cost of DarkStar Phase II was roughly what one would expect given the costs and accomplishments of these historical programs. The Global Hawk Phase II effort can best be compared to the two prototype development efforts of the LWF program. These three programs cost about the same once each is adjusted for known definitional differences in estimates. This is a favorable outcome given that conventional wisdom views the LWF prototype program as one of the most successful such programs in Air Force history.

The Global Hawk equivalent EMD is defined as Phases IIB and III of the ACTD, plus Phase IIC and the pre-EMD that bridge the ACTD to

formal EMD, plus Spirals 1 and 2 of EMD. The cumulative actual and projected costs of these six phases are compared to EMD expenditures in the F-16, F/A-18, and F-117 programs. The projected cost of Global Hawk's equivalent EMD is about $1.1 billion in FY 2001 dollars. This is only slightly more than half the inflation-adjusted EMD costs in the least expensive of the comparison programs, the F-16. It is slightly more than one-third more than the inflation-adjusted expense of the most appropriate EMD comparison program, that which developed the F-117.

A large band of uncertainty surrounds the future of Global Hawk development expenditures. After the definition of realistic upper and lower bounds, however, and regardless of which developmental path is taken, Global Hawk development costs will be considerably less than what one might expect given historical programs of roughly similar technological challenge and system complexity.

Appendix A

DEFINING PROGRAM PHASES AND CONTENT

The foregoing analysis of activities within the HAE UAV ACTD, their time frame, and their cost was accomplished through the study of the Agreements (and amendments) that were used as contractual instruments in this ACTD. This appendix draws from these documents to define program phases and their content.

APPROACH

The HAE UAV ACTD used seven Agreements and one letter contract as contractual instruments. Most of the contractor funding flowed through three of the Agreements: those with LMSW, Ryan, and RayES. This analysis focuses on these three Agreements but also includes information on the other four Agreements and the letter contract where relevant. As with traditional government contracts, each Agreement contains a number of CLINs.

DEFINITIONS

The HAE UAV ACTD program comprised the Tier II+ (Global Hawk), the Tier III–(DarkStar), and the CGS. The CGS effort is allocated to the Global Hawk and DarkStar development efforts according to the activities included in each of its CLINs. The CGS is not treated separately within the ACTD because the original HAE UAV program did

not include a CGS;[1] the Global Hawk and DarkStar development efforts were well under way when the CGS was added; and the CGS is no longer "common," as DarkStar has been canceled.

The Tier II+ program became known as the Global Hawk program beginning in mid-1995, after the completion of Phase I. The Tier III– program is better known as the DarkStar program and was referred to as such beginning in mid-1995, when its existence was formally acknowledged. The CGS was originally contracted as design modifications to the Global Hawk ground station. Later, it was contracted as the continuing development and production of ground stations for both air vehicles. Near the end of the ACTD, it was contracted as the development and production of ground stations just for Global Hawk.

In general, references made to the Tier II+ ACTD program apply to the period from April 1994 through September 2000, the approximate conclusion of the ACTD.[2] Those to the Global Hawk ACTD program apply to the period from May 1995 through the end of the ACTD. References to the Tier III– ACTD or DarkStar program refer to the period from June 1994 through the conclusion of program activities, which continued after program cancellation effective March 1, 1999. The term HAE UAV ACTD is used to include all activity content for the Tier II+ and Tier III– programs and the CGS over all phases of the ACTD. This covers the time period from the formation of the DARPA/DARO program office in February 1994 through the ACTD's approximate conclusion in September 2000.

The transition from ACTD to follow-on acquisition program took place over many months. As of the fall of 2000, multiple activities that were part of the ACTD had yet to be completed, and multiple follow-on development activities were already in work. Our analysis looks at all activities "on contract" as of June 30, 2000, and separates those belonging to the ACTD from those belonging to the follow-on development effort.

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[1] Although the CGS concept was proposed as early as November 1994 via a briefing by the HAE UAV joint program office to JROC, the effort was not definitized until March 1997, some three years after the HAE UAV ACTD program was established.

[2] There is no official end date to the ACTD—just a beginning date for the formal follow-on acquisition program determined by the Milestone II decision.

Table A.1 lists the CLINs from the Agreements that contribute to each phase in each program.[3] CLIN supporting activity in multiple phases in one or both programs are listed more than once. All CLINs included in the three Agreements through August 2000 are identified and allocated to the appropriate air vehicle programs and program phases. Activities that apply to both programs or to multiple phases are split evenly unless their content is understood well enough to determine a more accurate resource allocation.

In some cases, the Agreements do not associate activities (CLINs) with specific program phases. In our analysis, we allocate all appropriate activities according to the following general definitions:

- Phase I applies to the competitive portion of the Tier II+ program.

Table A.1

HAE UAV CLIN Allocation

Phase	Tier II+ ACTD	Tier III– ACTD
Phase I	Ryan Phase I; Loral Systems, Northrop Grumman, Orbital Sciences, and Raytheon Agreements	N/A
Phase II	Ryan Phase II Basic; CLINs 1, 2A–2F, 3–6, 8, 9, and 12–15; RayES CLINs 2–5, 7–10, 12, and 14	LMSW CLINs 1–7; RayES CLINs 1, 3–10, 12, and 14
Phase IIB	Ryan CLINs 7, 10, and 11; RayES CLINs 1, 11, 13, 15	LMSW CLINs 6, 8–11; RayES CLINs 1, 11, 13, and 15
Phase III	Ryan CLINs 2, 11, 16, 17, and 19; RayES CLINs 13 and 16	N/A
	Global Hawk Post-ACTD Activity	
Australian Demo	Ryan CLINs 18, and 21	N/A
Phase IIC	Ryan CLIN 20; RayES CLIN 17	N/A

[3]CLINs from the one letter contract in the HAE UAV ACTD were converted to CLINs in the Agreement that supplanted that letter contract. These activities are represented by their Agreement CLINs; thus, no letter-contract CLINs are listed in Table A.1. Sub-CLINs are considered part of their overarching CLIN and are not separately listed.

- Phase II represents the basic development effort as well as the procurement of the first two air vehicles and the first ground segment for each HAE UAV system. Follow-on development activities applying to the first two air vehicles and occurring during the period of performance of Phase II are considered part of that phase.
- Phase IIB represents follow-on procurement of air vehicles and ground segments produced during the time span of the ACTD in each HAE UAV system. Also included are the development tasks associated with improving the configurations of these assets.
- Phase III executes the operational demonstration, accomplishes specified developmental tasks for follow-on producibility and operational enhancements, and provides technical studies and analysis support occurring during the operational demonstration time frame for the Global Hawk program.
- Phase IIC is the procurement of Global Hawk air vehicles 6 and 7 and the updating of the original CGS to be compatible with the operational requirement of air vehicle 3 and subsequent. These activities are to be accomplished after the completion of the ACTD and are not considered part thereof.
- The Australian demonstration planning and preparation began during the ACTD and continues into FY 2001, the year of the actual demonstration. These efforts are not considered part of the ACTD.

CLIN TIME LINES

Figures A.1.A and A.1.B show the time line of each CLIN that is part of the Ryan Agreement as amended as of August 30, 2000. Figure A.2 show similar information for the LMSW Agreement. Figures A.3.A and A.3.B give the same information for the RayES Agreement. In each figure, shading is used to associate CLINs with specific program phases.

In the Global Hawk and DarkStar ACTD programs, some Ryan and LMSW CLINs apply to more than one phase. These instances occur when a CLIN is established in an earlier phase and its value is significantly increased in a later phase. The advent of the CGS also causes

CLINs to be split between the two air vehicle programs. We allocate CGS activities as follows:

- Efforts occurring substantially after June 2000 are not part of the ACTD.
- Efforts agreed to prior to September 1996 are completely attributable to the Tier III– program.
- Efforts agreed to after January 1999 that take place during the time frame of the ACTD are completely attributable to the Tier II+ program.
- For the 29 months between the latter two dates, CGS activities apply to either or both HAE UAV programs.

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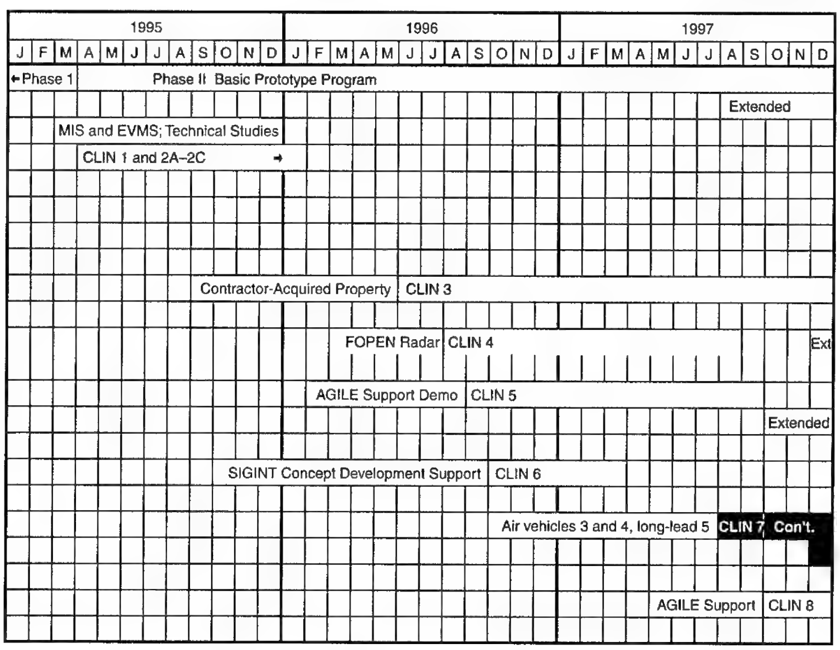

Figure A.1.A—Ryan Agreement by CLIN, 1995–1997

RANDMR1474-A.1b

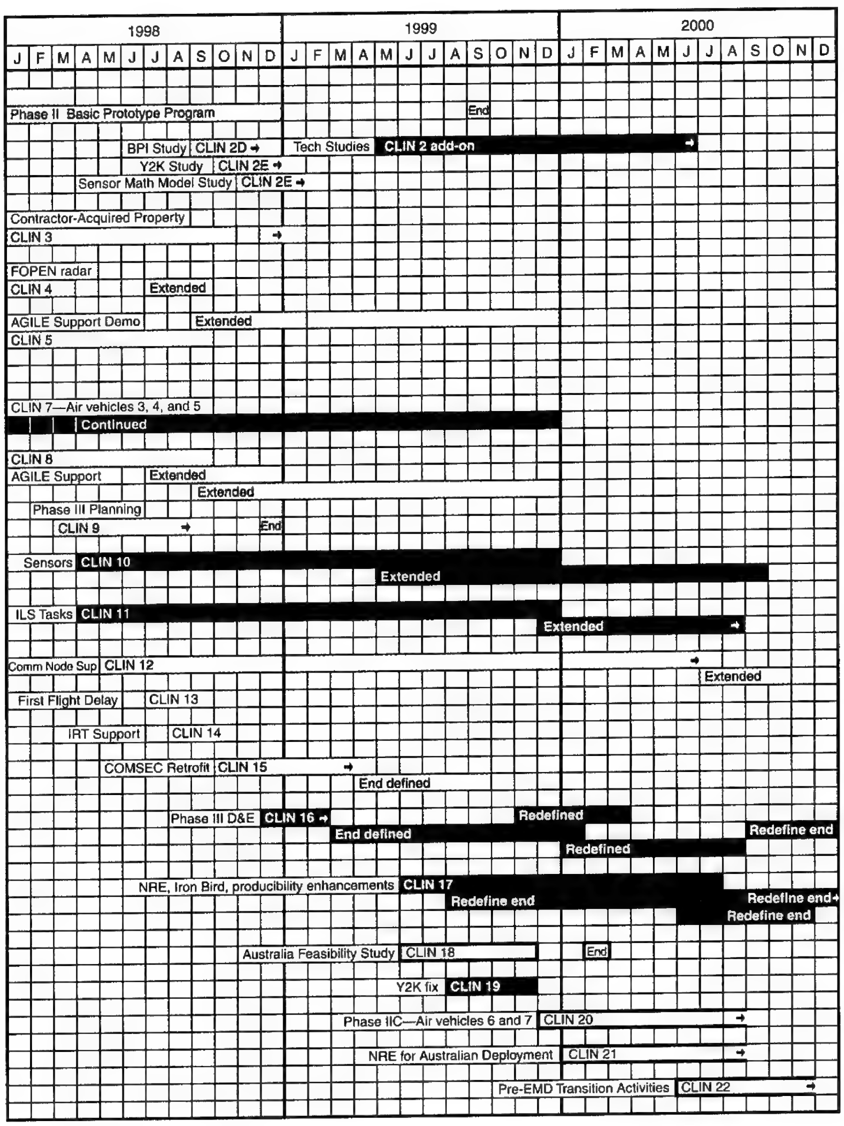

Figure A.1.B—Ryan Agreement by CLIN, 1998–2000

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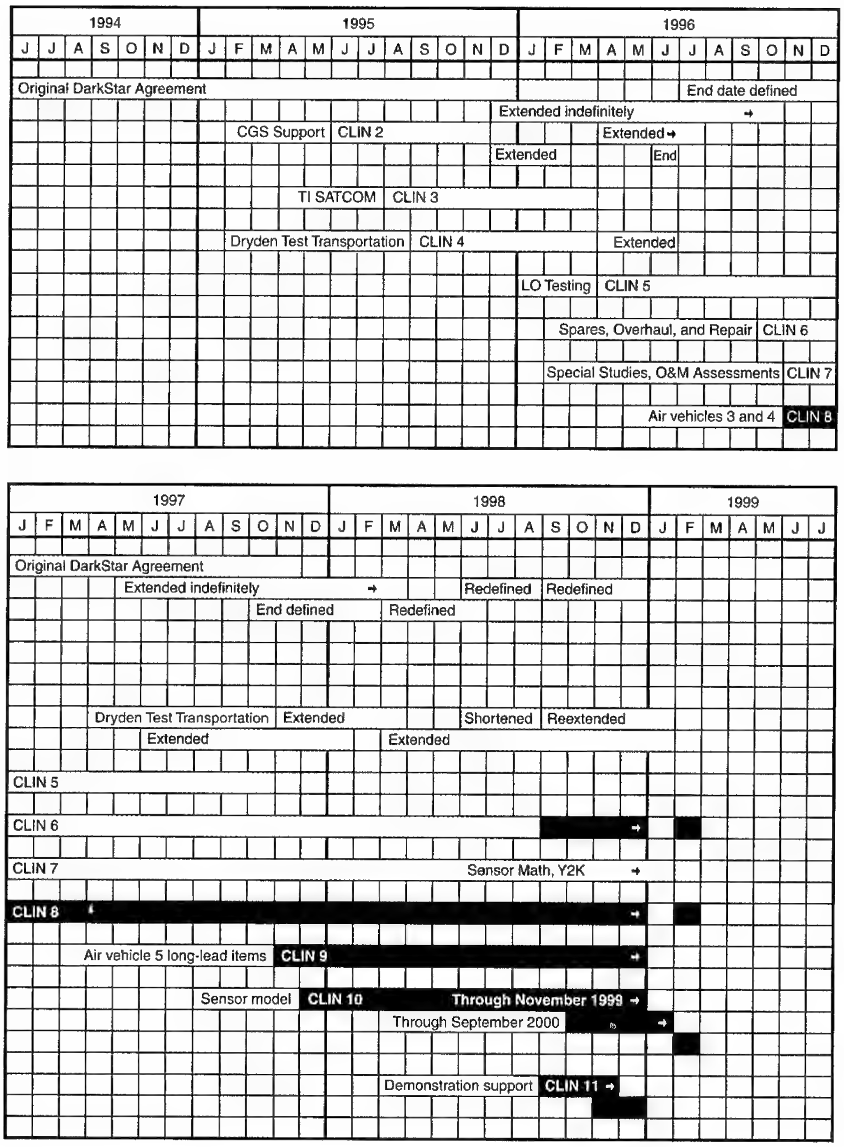

Figure A.2—LMSW Agreement by CLIN, 1994–1999

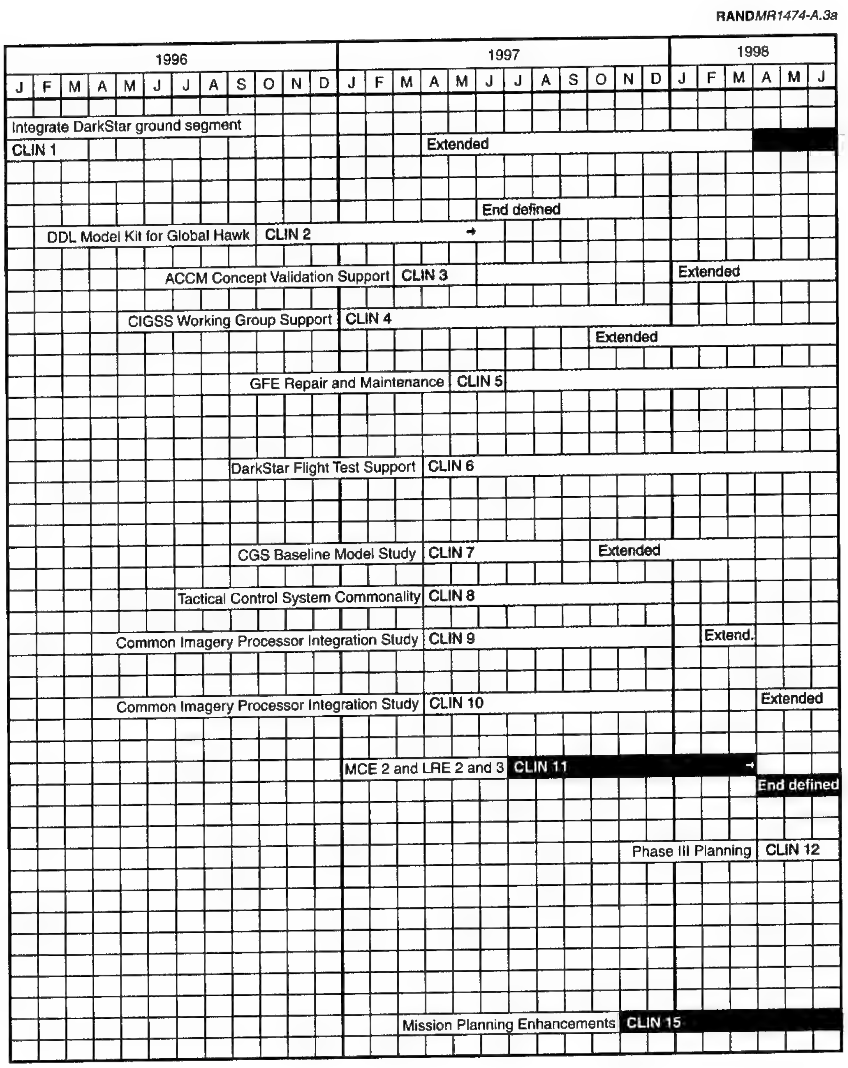

Figure A.3.A—RayES Agreement by CLIN, January 1996 to June 1998

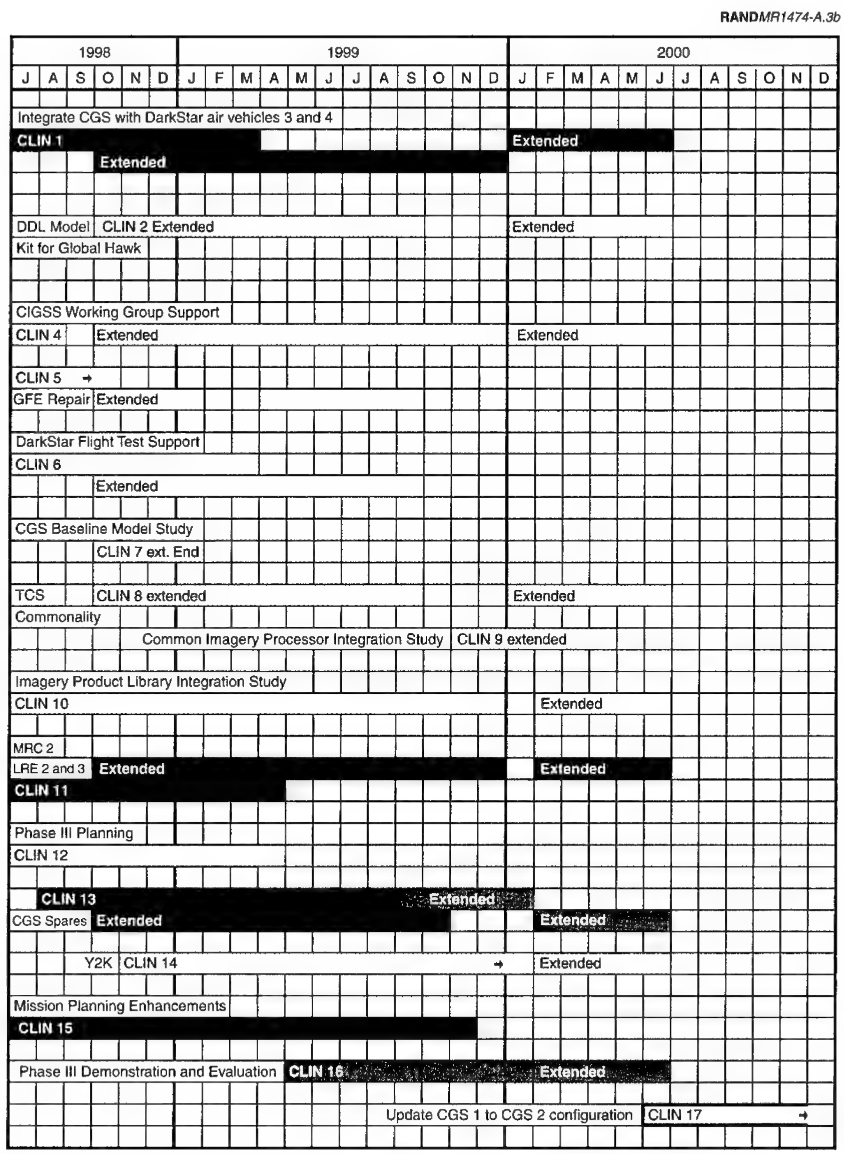

Figure A.3.B—RayES Agreement by CLIN, June 1998 to December 2000

Appendix B

COST, SCHEDULE, AND ACTIVITY CONTENT CHANGES BY PHASE AND FROM PHASE START

APPROACH

This analysis looks at the two air vehicle systems separately by ACTD program phase. The program's OTA status made it possible for the government to sign Agreements with the three prime contractors of the ACTD and to continuously amend those Agreements throughout the duration of the ACTD. Because the CGS is not a system in itself, and for the purpose of analysis, the activities assigned to the CGS contractor are allocated to the two air vehicle system contractors. This allows for the identification and allocation of all the costs and activities of the ACTD to the two HAE UAV systems developed within it.

In both the Tier II+ and Tier III– programs, cost and schedule growth is analyzed for each phase from the time that phase was defined through its conclusion. This analysis allows for a comparison of outcomes to those expectations defined at the time the work for that phase began.

TIER II+ PHASE I

Each of five Tier II+ contractor teams was awarded an Agreement valued at $4 million. This was the originally intended value for this six-month phase. There was no overrun on the part of the competing contractor teams; none was paid more than the $4 million. The

content planned for Tier II+ Phase I was completed largely as anticipated at its inception.

TIER II+ PHASE II—GLOBAL HAWK

Ryan was announced as the sole winner of Tier II+ Phase II on May 23, 1995. The amendment to its Agreement for the Phase II work was effective April 6, 1995, with a period of performance through February 1998. The amendment was not signed by all parties until August 4, 1995, calling into question what date should be associated with the agreed content and Phase II cost. The specified Agreement Value for Tier II+ Phase II was $158 million. The primary tasks of the original Phase II SOW included:

- Completion of the design and development of the Tier II+ system, including the ground segment;
- Definition of the system specification and all interfaces;
- Production of a development system consisting of two air vehicles, one set of sensors, one ground segment, and one support segment capable of demonstrating system performance; and
- Completion of initial flight and performance testing.

Of the total value, some $157.35 million was dedicated to the primary SOW tasks listed above using a cost plus incentive fee (CPIF) contractual arrangement. The remaining $640,315 covered Ryan CLINs 1 and 2A–2C using a cost plus fixed fee (CPFF) contractual arrangement. Ryan CLIN 1 provided $190,315 for Management Information Systems and Earned-Value Management Systems. Ryan CLINs 2A–2C were priced at $450,000 and were simply described as Tech Studies.

The Ryan Agreement was left substantially unchanged until March 1996, when the feasibility demonstration program to determine the effectiveness of employing AGILE support concepts was called for. At that time, the Agreement Value was left unchanged, but Ryan was asked to define the AGILE support effort at a not-to-exceed (NTE) price of $3.6 million. In June 1996, the government added Ryan CLIN 3 to transfer responsibility for acquiring certain government-furnished property to the contractor. The Agreement was amended

to reimburse the contractor directly for this property, effectively increasing its value by as much as $1 million. In November 1998, the cap on this provision was increased to $2 million. The final value was determined in March 2000 as $2.14 million. In August 1996, the government added Ryan CLIN 4 and $188,857 for support of the FOPEN Radar study. Later that month, another amendment added Ryan CLIN 5 and $3.55 million to formalize the feasibility demonstration program to determine the effectiveness of employing the AGILE support concept. The following month, the government added Ryan CLIN 6 and $37,308 for support of the SIGINT Concept Development Program. The first LRE was delivered to Ryan on November 1996 for air vehicle integration.

Most of the Agreement amendments for the remainder of 1996 and well into 1997 were for further obligations of funding. Amendment 18 in December 1996 brought the total funds obligated to Ryan in Phases I and II to $169.77 million. This was the first time the funds obligated had exceeded the Agreement Value of $166.76 million for the two phases ($4 million in Tier II+ Phase I and $162.76 million in Tier II+ Phase II). Total obligations continued to increased via amendments for another seven months—without modification of the Agreement Value. The largest disparity between the Agreement Value and funding obligated came with Amendment 23 dated July 16, 1997, where the latter exceeded the former by some $23 million.

In August 1997, the cost growth and schedule slip to date in the basic program were finally recognized. Provisions were made for continuing the basic Phase II effort up through a cost to the contractor of $228 million. The cost incentive fee under the prior arrangement was capped at the $3.524 million paid to date. A new incentive-fee pool was established with a value of $5.25 million payable for specific event accomplishments, and a cost share of 30 percent Ryan/70 percent government for expenditures between $206.25 million and $228 million was adopted. This brought the government's total potential liability for the CPIF work to $230.25 million.[1] Ryan additionally agreed to invest $3.1 million of corporate funds for a system integration lab (SIL). The schedule for the basic Phase II effort was extended

[1]All costs through $206,253,333 plus a $3.524 million fee previously paid plus 70 percent of the costs through $228 million plus a $5.25 million fee.

ten additional months through December 1998. Agreement completion for the entirety of Phase II was redefined as 60 days after successful accomplishment of all the flight test objectives in the master test plan dated November 15, 1995, or upon reaching total costs of $228 million.

In October 1997, the initial MCE was delivered to Ryan and the first LRE was deployed to Edwards Air Force Base in support of Phase II flight tests. In late 1997 and throughout 1998, additional work scope was added to Phase II. Ryan CLIN 8 added $1.46 million for AGILE support in October 1997, and Ryan CLIN 9 added $10,000 to begin Phase III planning efforts in March 1998. The funding for the latter was increased to $110,000 in April 1998 and was reduced to $56,370 in March 1999 to account for the actual scope of the effort. Support for the Airborne Communications Node Program began as Ryan CLIN 12 with NTE funding of $100,000 in April 1998. This effort's funding was increased to $580,280 two months later. Ryan CLIN 13 added $417,914 in June 1998 to cover contractor costs as a result of the government-directed delay of the first flight. Ryan CLIN 14 added $600,000 the following month to cover contractor costs as a result of the government-directed Independent Review Team (IRT) and closure of the subsequent safety verification issues (SVIs).

Ryan CLIN 2D, an addition to the CPFF portion of CLIN 2, added $100,000 in September 1998 for a BPI Ballistic Missile Defense Organization (BMDO) study. That same month, Ryan CLIN 15 added $347,401 for the Communications Security (COMSEC) Retrofit effort. Its value was subsequently increased to $395,000 and then reduced to $392,698 in March 1999. Ryan CLIN 2E, another addition to the CPFF portion of CLIN 2, added $250,000 in October 1998 for the Year 2000 (Y2K) Special Study. A third addition to the CPFF portion of CLIN 2, Ryan CLIN 2F, added $623,315 the next month for Preparation of the Global Hawk Sensor Math Model Data. This effort was transferred from Phase IIB. The value of Ryan CLIN 2D was increased to $114,069 in August 1999.

In February 2000, the basic program effort was restructured as a direct result of the destruction of Global Hawk air vehicle 2. Phase II completion was specified as occurring on September 30, 1999. Completion of Phase II was redefined as the delivery of one air vehicle rather than two. The final cost for the basic Phase II effort was

determined to be $224.31 million.[2] Total expenditures were about $226 million, some $2 million less than the maximum defined in the August 1997 Agreement amendment. Not included in the cost to the government figure were Ryan's $3.1 million cost share for improvements to the SIL and Ryan's $5.94 million cost share for Phase II overruns. When combined with the $4.2 million fee earned (included in the basic effort cost to the government), Ryan ended up losing some $4.84 million for its effort on the basic Phase II program.

In the beginning, the CGS effort consisted of integrating DarkStar ground segment functionality into that of Global Hawk. These early efforts are part of the DarkStar program. The first CGS task benefiting Global Hawk came in Letter Contract Modification 7 in September 1996, which added ES CLIN 3 for a Direct Downlink Demonstration Kit for Global Hawk.[3] This effort was initially priced at $1.2 million. Letter Contract Modification 10 dated March 21, 1997, added ES CLIN 8 for Advanced Cooperative Collection Management Concept Validation Support. This effort was priced at $48,341 and benefited both the Global Hawk and DarkStar programs.

On March 31, 1997, the contractual arrangement between the government and RayES was changed from a letter contract to an Agreement. The original effort became RayES CLIN 1, and four RayES CLINs were defined, including the redefining of two ES CLINs and the addition of two new efforts. ES CLIN 3 was redefined as RayES CLIN 2. Its value was subsequently increased to $1.34 million in June 1999. ES CLIN 8 was redefined as RayES CLIN 3. RayES CLIN 4, Common Imagery Ground/Surface System (CIGSS) Working Group Support, was initially priced at $9,000, increased to $34,000 in September 1997, and closed out with a value of $13,250 in June 2000. RayES CLIN 5, Repair and Maintenance of Government-Furnished Equipment, was initially NTE priced at $200,000, increased to $225,000 in September 1999, and closed out with a value of $175,000

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[2]All costs through $206.25 million plus 70 percent of the costs through $226.05 million plus total fees earned of $4.2 million.

[3]To distinguish between CLINs under the letter contract and their renumbering in the subsequent Agreement, we use the designation *ES* for CLINs defined under the former and *RayES* for CLINs redefined under the latter.

in June 2000. We were not able to discretely assign the efforts within RayES CLINs 3–5 to one HAE UAV program or the other; thus their cost is split between the two.

On May 21, 1997, four more RayES CLINs were added to the CGS effort. The cost of these was split between the Global Hawk and DarkStar programs for the same reason noted for RayES CLINs 3–5. RayES CLIN 7, the Common Ground Station Baseline Modifications Study, was initially priced at $192,524 and increased on several occasions to a final value of $497,634 in August 1999. RayES CLIN 8, Commonality Between the Tactical Control System and the HAE UAV CGS, was initially priced at $97,117 and was closed out with a value of $55,117 in June 2000. RayES CLIN 9, the Common Imagery Processor Integration Study, was initially priced at $97,065 and was closed out with a value of $22,715 in June 2000. RayES CLIN 10, the Imagery Product Library Integration Study, was initially priced at $74,350, increased to $547,297 in March 1998, and increased again to an NTE value of $710,000 in June 2000.

RayES CLIN 12, initially priced at $100,000 for Phase III planning, was added on March 31, 1998, and increased to $200,000 in February 1999. RayES CLIN 14 added $250,000 in October 1998 for a Y2K Study and was closed out with a value of $126,000 in June 2000. These two RayES CLINs were also split between the Global Hawk and DarkStar programs.

In summary, and as shown in Table B.1, Tier II+ Phase II began in April 1995 with an initial Agreement value between the government and Ryan of $158 million. In the following five-plus years, the basic portion of that effort grew from $157.3 to $224.3 million, or about $67 million. In the same time frame, Ryan CLINs 1, 2A–2F, 3–6, 8, 9, and 12–15 added scope and expense to the Global Hawk effort. In total, the Ryan effort increased $77.4 million for a total cost to the government of $235.4 million. The cost growth amounted to 49 percent.

The initial CGS effort did not involve activity attributable to the Tier II+ program. Nine RayES CLINs affecting both the Global Hawk and DarkStar programs and one RayES CLIN entirely attributable to the Global Hawk program were subsequently added to the RayES

Table B.1

Global Hawk Phase II Cost Growth Track (millions of TY dollars)

Global Hawk Phase II Content	Baseline April 6, 1995	Last August 31, 2000
Ryan Phase II basic	157.348	224.311
Ryan CLIN 1	0.190	0.190
Ryan CLIN 2A–2F (prior to May 1999)	0.450	1.437
Ryan CLINs 3–6	N/A	5.915
Ryan CLINs 8 and 9	N/A	1.521
Ryan CLINs 12–15	N/A	1.991
Ryan subtotal	157.988	235.365
Global Hawk–related Phase II CGS content	Baseline	Last August 31, 2000
RayES CLIN 2	N/A	1.340
RayES CLINs 3–5 (half)	N/A	0.118
RayES CLINs 7–10 (half)	N/A	0.643
RayES CLINs 12 and 14 (half)	N/A	0.163
RayES subtotal	0.000	2.264
Grand total	157.988	237.629

Agreement. The value of those efforts attributable to the Global Hawk was about $2.26 million. Adding the values of the Ryan and RayES CLINs together yields a total Tier II+ Phase II cost to the government of about $237.6 million. This represents nominal cost growth for the phase of about 50 percent over the April 1995 initial Agreement Value.

Tier III– Phase II Equivalent—DarkStar

LMSW and DARPA signed the original Agreement for the Tier III– program on June 20, 1994. The maximum possible Agreement Value for the Tier III– Technology Demonstrator Acquisition Program was set at $124.9 million. Depending on the costs expended by LMSW, the cost to the government could be as little as $118.1 million.[4] We choose the midpoint between these figures—that is, $121.5 mil-

[4]The pricing structure was such that the lower the expenditures by the contractor, the larger the fee earned. The maximum cost to the government included a fixed fee plus performance fee of $9.25 million, while the minimum cost to the government included a larger total fee of $15.4 million.

lion,—as the baseline estimate for the effort. The activity content from the effort's original SOW, which eventually became known as LMSW CLIN 1, was roughly equivalent in scope and content to the Phase II effort in the Global Hawk program. The two Phase II efforts are treated as equivalents in our analysis. LMSW CLIN 1 called for the design, manufacture, and delivery of the following:

- Two proof-of-concept flight vehicles, one of which is to be flightworthy;
- One radar sensor and one EO sensor;
- Two interoperable data links and two communications satellite (COMSAT) data links; and
- One LCRS.

The Agreement was left substantially unchanged until October 1995, when LMSW CLINs 2–4 were added. LMSW CLIN 2 was priced at $49,091 and called for the support of trade studies and for interface definition between the Tier III– system and the HAE UAV CGS. In June 1996, its value was increased to $107,373. LMSW CLIN 3 was priced at $108,000 and called for the support of T1 satellite communications (SATCOM) satellite link testing. LMSW CLIN 4 was priced at $702,000 and paid for contractor personnel transportation arrangements at the NASA Dryden Flight Research Center. In May 1998, this CLIN's value was increased to $965,304.

In December 1995, the basic Agreement arrangement was altered. Recognizing that the cost and schedule of the basic program would overrun, LMSW and the government agreed to continue using a cost-sharing arrangement. The maximum liability of the government was set at $132.43 million,[5] but a series of options left its total potential liability open-ended. Agreement completion was redefined as either the accomplishment of the performance goals or criteria or attainment of the expenditure ceiling of $143 million.[6] No completion date was specified.

[5]All costs through $115.7 million plus 50 percent of the costs up to $131.864 million plus the fixed fee of $3.08 million plus the maximum performance fee incentive of $5.57 million.

[6] This figure includes the contractor's cost share and excludes fee earned and paid.

In May 1996, Option 1 as defined in December 1995 was exercised. This increased the government's potential liability against LMSW CLIN 1 to $134.95 million.[7] LMSW CLIN 5 was also added at that time with an NTE value of $1.5 million. This effort provided for the LO testing of the first two DarkStar air vehicles. The testing is stated to be part of Phase IIB, but given the activity content characteristics defined for this analysis, we consider it part of the DarkStar program's Phase II effort. LMSW CLIN 5's NTE was increased to $2 million in August 1996 and was defined in October 1996 at a value of $2.02 million.

In July 1996, the basic program effort was redefined as a direct result of the crash of the first DarkStar aircraft. The primary change was to put the second air vehicle into flyable status, which was not called for in the original SOW. The Agreement now called for the delivery of one proof-of-concept flight vehicle instead of two and one long-wave common data link instead of two interoperability data links. The other deliverables remained unchanged. The period of performance was extended through December 1997. These changes increased the government's potential liability against LMSW CLIN 1 to about $166 million.[8] Provisions outlining cost-sharing arrangements were specified to apply if costs grew even further. The total possible value of LMSW CLIN 1 and the government's liability for it were left open-ended.

LMSW CLIN 6, providing $7.855 million for spares, overhaul, and repair, was added in October 1996. In September 1998, its value was increased by an NTE amount of $500,000. The LMSW Agreement closeout in April 2000 put the final value of LMSW CLIN 6 at $7.98 million. This CLIN is split between Phase II and Phase IIB, as was system support for the testing of air vehicles 2–4. In November 1996, LMSW CLIN 7 was added with a value of $921,998 for Operations and Maintenance Assessments. In September 1998, $345,641 was added for a Sensor Math Model Study. The following month, $250,000 was

[7]All costs through $115.7 million plus 50 percent of the costs up to $136.9 million plus the fixed fee of $3.08 million plus the maximum performance fee incentive of $5.57 million.

[8]All costs through $115.7 million plus 50 percent of the costs up to $136.9 million plus 67.4325 percent of the costs up to $183 million plus the fixed fee of $3.08 million plus the maximum performance fee incentive of $5.57 million.

added for a Y2K Special Study. This brought the total value of LMSW CLIN 7 to $1.67 million. The efforts embodied in LMSW CLIN 7 were ultimately valued at $2.728 million in the April 2000 final agreement closeout.

Under the terms established in July 1996, the government's potential liability under LMSW CLIN 1 was increased three additional times. In September 1997, it became approximately $174.1 million.[9] At that time, the period of performance was extended to March 1998. In March 1998, it increased to $177.5 million,[10] and the period of performance was again extended through June 1998. In June 1998, it increased to $180 million,[11] and the period of performance was extended a third time through August 1998.

A new cost-sharing arrangement was specified in September 1998. Expenditures between $205 million and $220 million were to be split by LMSW and the government. The government was to pick up the first half of these expenditures—that is, those between $205 million and $212.5 million. LMSW would absorb the remainder up to $220 million. This arrangement put the government's total potential liability for LMSW CLIN 1 at $189.5 million.[12] Agreement completion was redefined, the agreement termination criteria were rewritten, and the period of performance was extended through the end of 1998. The DarkStar program cancellation decision was made on January 29, 1999. LMSW Agreement Amendment 54 made it official

[9]All costs through $115.7 million plus 50 percent of the costs up to $136.9 million plus 67.4325 percent of the costs up to $195 million plus the fixed fee of $3.08 million plus the maximum performance fee incentive of $5.57 million.

[10]All costs through $115.7 million plus 50 percent of the costs up to $136.9 million plus 67.4325 percent of the costs up to $200 million plus the fixed fee of $3.08 million plus the maximum performance fee incentive of $5.57 million.

[11]All costs through $115.7 million plus 50 percent of the costs up to $136.9 million plus 67.4325 percent of the costs up to $200 million plus 50 percent of the costs up to $205 million plus the fixed fee of $3.08 million plus the maximum performance fee incentive of $5.57 million.

[12]All costs through $115.7 million plus 50 percent of the costs up to $136.9 million plus 67.4325 percent of the costs up to $200 million plus 50 percent of the costs up to $220 million plus the fixed fee of $3.08 million plus the maximum performance fee incentive of $5.57 million plus the cost incentive fee of $2 million.

as of March 1, 1999. In the final agreement closeout dated April 2000, the CLIN 1 cost to the government was $181.932 million.[13]

The CGS effort contracted directly with RayES was initiated on January 24, 1996, with an initial NTE value of $1 million and a period of performance through March 31, 1996. This Interface Definition and Mission Planning Software Development effort, entitled HAE UAV Ground Segment Tier III– Integration, began as a letter contract that eventually became ES CLIN 1. Through the end of August 1996, the effort's period of performance was extended four times to September 30, 1996. On March 29, 1996, its NTE value was increased to $2.1 million.

Letter Contract Modification 7 in September 1996 added scope to ES CLIN 1 and defined and added ES CLINs 2 and 3. The increased scope called for additional analysis, integration, and test. ES CLIN 2 provided data for ES CLIN 1. The NTE value for the combined effort of ES CLINs 1 and 2 was increased to $4 million. ES CLIN 3 applied to Global Hawk. Four additional ES CLINs were outlined as options. The period of performance for ES CLIN 1 was extended to December 20, 1996, and that for ES CLIN 2 was defined as September 30, 1996, through February 28, 1998.

By early March 1997, the ES CLIN 1 NTE value had reached $8 million, and its period of performance was extended twice more to a new final date of March 31, 1997. As previously discussed, on that date the contractual arrangement between the government and RayES was changed from a letter contract to an Agreement. ES CLINs 1 and 2 became RayES CLIN 1. This effort was defined as the design, development, integration, and test of modifications to the Global Hawk ground segment to accommodate the operations of DarkStar.

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[13]All costs through $115.7 million plus 50 percent of the costs up to $136.9 million plus 67.4325 percent of the costs up to $200 million plus 50 percent of the costs up to $220 million plus the fixed fee of $3.08 million.

A target value for RayES CLIN 1 was set at $25.826 million, including a target fee of about $1.9 million.[14] A milestone-related award-fee pool totaling $1 million was also set up, bringing the government's maximum liability for the CLIN to about $27.4 million.[15] RayES CLIN 2 applied to the Global Hawk program. The efforts in RayES CLINs 3–5 benefit both Global Hawk and DarkStar and are thus split between the programs.

In May 1997, DarkStar flight test support was broken out from RayES CLIN 1 and was separately accounted for as RayES CLIN 6. The new target value for RayES CLIN 1 was $25.691 million, and the target fee was slightly reduced from its original value. The second LRE, which is considered part of the initial CGS, was delivered to Boeing in November 1998 for DarkStar integration. RayES CLIN 6 was initially priced at $299,548 and was increased to $315,621 in September 1999. The efforts in RayES CLINs 7–10, 12, and 14 benefit both Global Hawk and DarkStar and are thus split between the programs.

In summary, and as shown in Table B.2, Tier III– Phase II began with the Agreement between the government and LMSW in June 1994. The value was between $118.1 million and $124.9 million, with the mean of these values serving as our baseline. The government's final cost for the basic effort, which concluded almost six years later, was $181.9 million. In the same time frame, LMSW CLINs 2–7 added scope and cost to the DarkStar effort. The added LMSW CLINs were valued at a total of $9.918 million. The cost of the total LMSW effort grew from $121.50 million to $191.85 million, or some 58 percent.

The original CGS effort contracted for between the government and RayES began in January 1996 but was not defined and priced until March 1997. Nine RayES CLINs affecting both the Global Hawk and DarkStar programs and one RayES CLIN adding scope only to the DarkStar effort were added to this Agreement. The cost of the total effort grew from $26.8 million to $27.9 million, or just 4.1 percent.

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[14]The pricing structure was such that the lower the expenditures of the contractor, the larger its fee. The maximum price to the government called for no fee, while the minimum price maximized the fee at $2,369,366.

[15]The maximum cost of $26.4 million plus the maximum milestone-related award fee.

In analyzing the total DarkStar program cost for Phase II, the baseline estimate should not include the CGS effort because it was not envisioned at the program's inception. The final cost of the phase is $219.8 million, the sum of the LMSW and RayES efforts. This represents a nominal cost growth of 81 percent over the June 1994 initial value of $121.5 million. Of the roughly $98.3 million increase, $60.3 million is attributable to cost growth in the basic effort, $28 million to the addition of the CGS effort, and the remaining $10 million to other added scope.

Table B.2

DarkStar Phase II Cost Growth Track (millions of TY dollars)

DarkStar Phase II Content	Baseline June 20, 1994	Last April 28, 2000
LMSW CLIN 1 (baseline)	121.500	181.932
LMSW CLINs 2–4	N/A	1.180
LMSW CLIN 5	N/A	2.020
LMSW CLIN 6 (half)	N/A	3.990
LMSW CLIN 7	N/A	2.728
LMSW subtotal	121.500	191.850
DarkStar-related Phase II CGS content	Baseline March 31, 1997	Last various dates
RayES CLIN 1 (baseline)	25.826	25.691[a]
RayES CLINs 3–5 (half)	N/A	0.118
RayES CLIN 6	N/A	0.316
RayES CLINs 7–10 (half)	N/A	0.643
RayES CLINs 12 and 14 (half)	N/A	0.163
RayES award fee	1.000	1.000
RayES subtotal	26.826	27.931
Grand total	148.326	219.781

[a]This is the last value associated with the tasks for CGS integration involving Tier III– air vehicles 1 and 2. Activities contracted for under this CLIN beginning March 31, 1998, are associated with air vehicles 3 and subsequent for both HAE UAV configurations.

Tier II+ Phase IIB—Global Hawk

The activity content of the Tier II+ Phase IIB effort is a subset of what was called for in Phase III under the originally envisioned Tier II+ ACTD program plan. Amendment 24 to the Ryan Agreement added

Phase IIB to the Tier II+ program on August 4, 1997. The phase initially took form as Ryan CLIN 7 with an NTE value of $11 million. Amendment 24 authorized the fabrication of Global Hawk air vehicles 3 and 4 along with long-lead items for air vehicle 5. Sensors for these air vehicles were not included in the Ryan CLIN 7 SOW. Nonrecurring engineering tasks to improve the configuration of air vehicles 3 and subsequent were included in the effort. A baseline system specification was added to the Agreement as well. The contractor was asked to submit a proposal for these efforts leading to an award on October 30, 1997. The nonrecurring engineering tasks included the following:

- The structuring and implementation of an earned-value management system that included the establishment and maintenance of a UFP tracking system;
- The beginnings of an ILS system as needed to support air vehicle flight testing;
- The upgrading of the aircraft's engine and payload;
- Improvements to simulation capabilities and drawings;
- Implementation of long-term software support;
- A bootstrapping study to identify "single-event upsets" and remedies to them; and
- Producibility enhancements designed to reduce the UFP.

For the first seven months of the Ryan effort, the Tier II+ Phase IIB effort was funded as needed. No cost goal, incentives, or cost caps were specified. The contractual arrangement was cost plus award fee (CPAF), and the value was to be determined (TBD). Funding was more than doubled to $22.06 million in December 1997 and was increased again in March 1998 to more than $37 million. Additional NRE tasks involving air vehicle instrumentation and system support equipment were added with the second funding increase.

The task description document (TDD) and the total funding and fee for Ryan CLIN 7 were finally defined in Amendment 35 on March 31, 1998. The effort was expanded to include the option to complete air vehicle 5 and was priced under a CPAF arrangement at $82.687 million. Amendment 35 also added Ryan CLINs 10 and 11 as parts of

Tier II+ Phase IIB. The former called for $17.704 million for an ISS and the latter for $5.302 million for ILS tasks. Both values were CPAF. The ILS tasks included $300,000 for technical manuals; $388,532 for training; $4 million for spares; $289,673 for reliability and maintainability enhancements; and a fixed fee of $323,583.

An award-fee pool for the Tier II+ Phase IIB effort, Ryan CLINs 7, 10, and 11, was set up with a maximum value of $5.118 million. This put the government's total expected liability for the phase at $110.81 million. Major milestones in the award-fee plan and the period of performance for the three CLINs stretched through December 1999. Tier II+ Phase IIB completion was defined as 60 days after successful accomplishment of air vehicle function acceptance testing for air vehicles 3, 4, and 5 and accomplishment of UAV air vehicle system checkout, with the ISS procured via Ryan CLIN 10.

In September 1998, $5.5 million was added to Ryan CLIN 10 for another SAR and $623,315 was added for Preparation of Global Hawk Sensor Math Model Data. The latter was subsequently transferred to the Phase II effort on November 9, 1998. In March 1999, the remaining milestone schedule dates in the Tier II+ Phase IIB award-fee plan were removed. Two months later, the SAR added the previous September was converted to a complete ISS, and the corresponding funding was increased from $5.5 million to $11.5 million. This increased the value of Ryan CLIN 10 to $29.2 million. The period of performance for the second ISS was estimated as extending through September 2000. In February 2000, the value of Ryan CLIN 7 was decreased by $1.8 million as the accounting for the purchase of a spare engine was moved to Ryan CLIN 11. The value of Ryan CLIN 11 was increased by the accounting change, but given its timing, the increase is accounted for under Phase III D&E.

The CGS Phase IIB effort was initiated in June 1997 with authorization for the procurement of long-lead items for the second CGS. This took the form of RayES CLIN 11. The contractual arrangement for hardware procurement was directly between RayES and the program office.[16] In a manner similar to what occurred in the Ryan Phase IIB

[16]The first Global Hawk ground segment effort was subcontracted to RayES by Ryan.

effort, the first eight-plus months of RayES effort toward CGS Phase IIB was funded as needed. No cost goals or incentives were specified. The effort was given an NTE value of $2.884 million at its inception. The NTE value was increased to $5.134 million in October 1997. Long lead for an additional LRE was added to CLIN 11 in January 1998, and the CLIN's NTE value was increased to $9.884 million.

The effort was defined and priced at $17.566 million to include the procurement of CGS 2 plus that of LRE 3. This occurred on March 31, 1998, the same date the Tier II+ Phase IIB air vehicle efforts were defined. The assets provided under RayES CLIN 11 clearly supported both the Global Hawk and DarkStar programs, and thus the CLIN's value is split between the two programs.

In July 1998, RayES CLIN 13 and $1.5 million were added to provide CGS spares. This effort was defined in August 1999 and was priced at $2.573 million, with a period of performance extending through January 2000. The spares procured in this effort were most likely intended to support both Global Hawk and DarkStar air vehicle operations in Phase IIB through the end of the ACTD. Given that DarkStar was canceled before the beginning of Phase III, the value of RayES CLIN 13 is split between Tier III– Phase IIB and Tier II+ Phases IIB and III.[17]

Mission planning enhancements were called for under RayES CLIN 1 in October 1997. This effort benefited both aircraft configurations and had an initial NTE value of $350,000. The following January, the NTE value was increased to $730,000. The effort was defined on September 25, 1998, and was priced at $4.096 million. The effort was removed from RayES CLIN 1 on February 18, 1999, and became RayES CLIN 15 with an increased value of $5.101 million. Some of the mission planning enhancement activity of RayES CLIN 15 affected the DarkStar program; thus 80 percent of the effort's cost is accounted for in the Global Hawk Phase IIB effort.

The second LRE was returned from Boeing (where it was undergoing DarkStar integration) to Raytheon in February 1999, retrofitted to a Global Hawk–only configuration, and delivered to Ryan in June 1999.

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[17]Given the flight operation tempo of each of these phases, a 10 percent/30 percent/60 percent split was assumed.

Both the Ryan and RayES efforts for Phase IIB were begun in mid-1997 but were not defined and priced until March 1998. For the purpose of determining cost growth, their values as of March 31, 1998, are used as a baseline.

In summary, and as shown in Table B.3, the cost of Tier II+ Phase IIB grew modestly. The cost for Global Hawk activities grew from $110.8 million to $120.5 million; CGS activities associated with Global Hawk grew from $8.8 million to $13.6 million. In aggregate, the total Tier II+ Phase IIB cost increase of 12 percent was almost completely attributable to the increased work scope—that is, to the added ISS and mission-planning upgrades.

Tier III– Phase IIB—DarkStar

We consider the initiation of DarkStar air vehicle 3 and subsequent procurement the beginning of Tier III– Phase IIB. On November 8, 1996, LMSW CLIN 8 authorized long-lead activities for air vehicles 3 and 4 with an NTE value of $4.47 million. The NTE was left unchanged until the effort was defined on May 13, 1997, in a CPIF form

Table B.3

Global Hawk Phase IIB Cost Growth Track (millions of TY dollars)

Global Hawk Phase IIB content	Baseline March 31, 1998	Last August 31, 2000
Ryan CLIN 7	82.687	80.887
Ryan CLIN 10	17.704	29.204
Ryan CLIN 11 (prior to February 2000)	5.302	5.302
Ryan award-fee pool	5.118	5.118
Ryan subtotal	110.810	120.511
Global Hawk–related Phase IIB CGS content	Baseline March 31, 1998	Last August 31, 2000
RayES CLIN 11 (half)	8.783	8.783
RayES CLIN 13 (30 percent)	N/A	0.772
RayES CLIN 15 (80 percent)	N/A	4.081
RayES subtotal	8.783	13.636
Grand total	119.593	134.147

and with a target value of $58.375 million. The maximum possible obligation to the government was set at $60.54 million. Efforts beyond the expenditure ceiling required both parties' consent. The terms applying to continuation were TBD. The Agreement was changed to give DARPA unilateral program termination rights at any time. For LMSW CLIN 8, the incentive fee arrangement was similar to that in Phase II of the DarkStar program; the lower the final expenditures by LMSW, the higher the incentive fee for the work performed.

The work scope included the two air vehicles configured for compatibility with the CGS, one SAR payload, and one EO payload. The $10 million UFP requirement for air vehicles 11–20 was reiterated in the LMSW CLIN 8 SOW. The effort also included the following NRE studies and NRE items to be included on the two new air vehicles:

Studies

- An alternating current to direct current converter;
- Air vehicle system improvement;
- Air traffic control (ATC) voice relay capability; and
- An ultrahigh-Frequency (UHF) SATCOM using demand assign multiple-access compliance.

Items

- Landing gear redesign and incorporation;
- Navigation lighting system redesign and incorporation;
- Implementation of a Mode 4 identification friend or foe (IFF) transponder with mode S;
- Creation of a capability for the control of multiple (three) simultaneous air vehicles;
- Redesign and incorporation of the air vehicle as needed to meet radar cross section (RCS) design predictions; and
- Redesign and incorporation of a retractable upper blade antenna.

As noted previously, half of the activities and cost of LMSW CLIN 6, which provided spares, overhaul, and repair, is presumed to apply to Phase IIB. LMSW CLIN 9, added in November 1997 with an NTE value of $3 million, provided long-lead items for air vehicle 5. In July 1998, the effort was defined with no change in value. In November 1997, LMSW CLIN 10 and $3.452 million were added for a 24-month effort to modify the CA-236 Sensor for Electro-Optical Framing. In September 1998, this effort's funding was increased to $3.5 million and its period of performance was extended nine additional months.

LMSW CLIN 8 was redefined in a new SOW dated January 13, 1998. This brought the target value of the CLIN to $66.698 million with the government's maximum liability capped at $70.169 million. Most of the changes from the original SOW provided for enhanced robustness and flightworthiness of the two air vehicles to be procured. LMSW CLIN 8 was expanded again in December 1998 with additional NRE and studies per the January 13, 1998, SOW and with configuration changes for DarkStar air vehicles 3 and 4 per the October 6, 1998, SOW. This increased the target value to $67.713 million and the NTE value to $71.232 million. Upon Agreement closeout in April 2000, the government's final liability against LMSW CLIN 8 was set at $70.795 million.

LMSW CLIN 11, with an NTE value of $500,000, was added in August 1998 to provide Support for Follow-on Test and Demonstration Activities. This CLIN applies to all DarkStar air vehicles and is for activities lying beyond the scope of LMSW CLIN 6; thus, it is considered part of the Phase IIB effort. Its value was increased to $1.25 million the following month and to $3.65 million the month thereafter.

Activities from several RayES CLINs constitute the CGS effort associated with Tier III– Phase IIB. On March 31, 1998, NRE activities were added to the original SOW to update the CGS configuration to accommodate DarkStar air vehicles 3 and 4. The target value for CLIN 1 was increased by $8.535 million.[18] The award fee for RayES CLIN 1 was increased from the original $1 million to $1.75 million. These in-

[18]RayES CLIN 1 now had a total target price of $34.227 million, including a target fee of $2.512 million.

creases are considered to be part of the cost to the government for Phase IIB. As noted previously, half of the activities and cost of RayES CLIN 11, which provided CGS 2 and LRE 3, apply to the DarkStar program, as does 10 percent of the value of RayES CLIN 13, which provided CGS spares to support DarkStar flight test. In addition, 20 percent of CLIN 15 for Mission Planning applies to the Tier III– Phase IIB effort.

In summary, and as shown in Table B.4, the cost of Tier III– Phase IIB grew substantially from its definition in May 1997. The cost for DarkStar activities grew from $62.3 million to $84.9 million. CGS activities associated with DarkStar grew from $18.1 million to $19.3 million. In aggregate, total Tier III– cost growth for this phase was about 30 percent. Roughly half of the growth was due to increased costs to the basic effort of the phase—that is, to the building of the third and fourth air vehicles. Most of the remaining cost growth was due to increased work scope: the long lead for the fifth air vehicle, sensor modification, and follow-on test and demonstration activities.

Table B.4

DarkStar Phase IIB Cost Growth Track (millions of TY dollars)

DarkStar Phase IIB Content	Baseline May 13, 1997	Last April 28, 2000
LMSW CLIN 6 (half)	3.928	3.990
LMSW CLIN 8	58.375	70.795
LMSW CLINs 9–11	N/A	10.150
LMSW subtotal	62.303	84.935
DarkStar-related Phase IIB CGS content	Baseline March 31, 1998	Last April 28, 2000
RayES CLIN 1 (addition)	8.535	8.535
RayES CLIN 11 (half)	8.783	8.783
RayES CLIN 13 (10 percent)	N/A	0.257
RayES CLIN 15 (20 percent)	N/A	1.020
RayES award fee (addition)	0.750	0.750
RayES subtotal	18.068	19.345
Grand total	80.371	104.280

As a result of the DarkStar program's termination in early 1999, it is not known how much more the cost of this program phase would have increased. Not all activities were completed at the time of cancellation, and it is impossible to know how close LMSW was to completing these activities. Air vehicles 3 and 4 were delivered, but neither flew. Had the program continued, a larger cost growth figure would certainly have resulted.

Tier II+ Phase III—Global Hawk

Global Hawk Agreement Amendment 48, dated December 11, 1998, established the Phase III D&E in the form of Ryan CLIN 16. The NTE value for this work was set at $64 million. The October 21, 1998, SOW called for preplanning for D&E testing, support of D&E testing with air vehicles 1–5 throughout Phase III, and NRE engineering and support. The SOW gave a tentative list of exercises to be supported by Ryan, beginning in April 1999 and concluding in January 2000. Ryan was responsible for operating the aircraft and for collecting the imagery throughout the operational demonstration. NRE tasks included component upgrades and additions, improvements in testing methods and equipment, maintenance task analyses and documentation, and ISS frequency reallocations.

Ryan CLIN 16 was defined in a revised SOW dated March 12, 1999. According to the program office, Ryan proposed more than it had in mind. Unwanted content was removed, and the CLIN's value was reduced to $45 million. The changes from the original proposed scope of work were almost exclusively in the specified NRE tasks. These changes were as follows:

- Maintenance task analysis and documentation were reduced.
- Integrated Mission Management Computer (IMMC) Interface Unit (IIU)/Power Distribution Control Unit (PDCU) hardware and software upgrades were scaled back or removed.
- IMMC software enhancements were scaled back.
- Upgrades to the Automated Regression Test System were reduced.

- Consolidated system test and simulation capabilities were added.
- Ground Moving Target Indicator (GMTI) maturing was removed.
- Survivability suite procurement, capability and logistics enhancements, and flight test were scaled back or removed.
- Engineering studies "as requested" throughout Phase III were added.

On May 21, 1999, $500,000 was added to Ryan CLIN 16 to procure additional spares in support of the operational demonstrations. In November 1999, the value of the award-fee portion of Ryan CLIN 16 was reduced slightly to reflect what had been earned. Additional tasks with an NTE value of $12 million were added to Ryan CLIN 16 via an ASC/RAV letter dated December 9, 1999.[19] In April 2000, more tasks were added and the value was increased again, this time by about $9.5 million, giving a new value of $67.094 million. In late November 1999, the period of performance for Ryan CLIN 16 was extended through March 2000. Two months later it was extended again, this time through August 2000. When that date came to pass, it was extended an additional four months to a final date of December 31, 2000.

On May 7, 1999, $10 million was added to Ryan CLIN 2 for additional Technical Studies and Analysis. Given the time frame of this addition and because this action appears to fund the last item on the list of changes in the revised Ryan CLIN 16 SOW, this effort is considered part of Phase III. Y2K fixes were authorized under Ryan CLIN 19 on August 30, 1999, with an NTE value of $350,000. This effort was defined in April 2000 and was valued at $210,208.

On May 21, 1999, Ryan CLIN 17 was added with an NTE value of over $19 million and a period of performance through July 2000. The July 1, 1999, SOW for Ryan CLIN 17 called for the fabrication of a Developmental Test Model (DTM) and NRE and tooling improvements. The former accounted for two-thirds of its value and the latter one-third. The DTM is essentially an air vehicle less the ISS, communications and navigation suites, engine, wing, and various

[19]As indicated in Ryan Amendment 72 dated March 31, 2000.

flight-related airframe and air vehicle system items. NRE and tooling tasks included changes/improvements in airframe structure, system tooling, mechanical/electrical subsystems, and supplier producibility. In late July 1999 this activity was priced at $14.883 million and its period of performance was extended an additional month. In June 2000 it was extended through December 2000, and on August 31, 2000, it was again extended this time through February 2001. The second extension was accompanied by a price reduction to $13.683 million.

In February 2000 the value of Ryan CLIN 11, which initially provided technical manuals, training, and spares for Phase IIB, was increased by $4.117 million to repair and procure flight, mission-critical spares, and component repairs in support of Phase III flight activity. By August 2000 its value had increased twice more for a total addition applicable to Phase III of $4.21 million.

The CGS Phase III effort was initiated on March 30, 1999. By this time the DarkStar program had been canceled. All Phase III CGS efforts are therefore attributable to the Tier II+ program. On that date RayES CLIN 16 for CGS support of D&E was established and valued at $12.204 million, including a fixed fee and an award fee of $603,116 each. In September 1999, the demonstration of the direct downlink to the Navy Joint Service Imagery Processing System (JSIPS) was added as a sub-CLIN. This effort was given an NTE value of $390,000. Its value was subsequently reduced to $85,000 in June 2000. As noted previously, 60 percent of RayES CLIN 13 is presumed to apply to the Phase III effort. At the inception of that effort, the CLIN was valued at $1.5 million. By late 1999, its value had increased to $2.573 million.

The second MCE was delivered to Ryan in September 1999. The initial MCE was returned to Raytheon in December 1999 for an upgrade and was then returned to Ryan in March 2000. The third LRE (considered part of the second CGS) was delivered to Ryan in November 1999. The initial LRE was returned to Raytheon in February 2000 for an upgrade and was returned in June 2000. All LREs and MCEs supported Phase III testing at some point.

In summary, and as shown in Table B.5, the cost of Tier II+ Phase III grew substantially from the time of its inception in December 1998. The total cost of Phase III for Global Hawk activities increased from \$64 million to \$95.2 million, or some 49 percent. Almost all of the increase was for added content such as nonrecurring efforts in the areas of technical studies and analytical support, the building of the DTM, and producibility enhancements. The cost of CGS activities associated with the Global Hawk Phase III grew only slightly, from \$13.1 million to \$13.8 million. The cost for the D&E operations portion of Phase III did not increase, with the program office stating that this effort accounted for \$37 million of the total. The Tier II+ Phase III cost increase of 41 percent in aggregate, from \$77.1 million to \$109 million, was almost completely due to added activity content.

Table B.5

Global Hawk Phase III Cost Growth Track (millions of TY dollars)

Global Hawk Phase III Content	Baseline December 11, 1998	Last August 31, 2000
Ryan CLIN 16	64.000	67.094
Ryan CLIN 2 (addition)	N/A	10.000
Ryan CLIN 11 (additions)	N/A	4.210
Ryan CLIN 17	N/A	13.683
Ryan CLIN 19	N/A	0.210
Ryan subtotal	64.000	95.197
Global Hawk–related Phase III CGS Content	**Baseline March 30, 1999**	**Last August 31, 2000**
RayES CLIN 13 (60 percent)	0.900	1.544
RayES CLIN 16	12.204	12.289
RayES subtotal	13.104	13.833
Grand total	77.104	109.030

Appendix C

COST, SCHEDULE, AND ACTIVITY CONTENT CHANGES BY PROGRAM AND FROM ACTD START

APPROACH

If one is to track the cost and schedule changes in the HAE UAV ACTD from its inception, an understanding of each program's content and the evolution of that content is needed. This requires that each program be baselined at its inception and its content reviewed at the beginning of each phase. In each program, the activity content, cost, and schedule of each phase is compared to its original plan. That plan is circa April 1994 for Global Hawk and the latter half of CY 1994 for DarkStar. This allows for a comparison of outcomes to expectations—with those expectations defined at the inception of system development. As in previous sections, the CGS effort is allocated—according to the activities included in each of its CLINs—to the Global Hawk and DarkStar development efforts.

TIER II+ PROGRAM

According to the HAE UAV Phase I solicitation dated June 1, 1994, the planned program structure was as follows:

- **Phase I:** A six-month effort by three contractor teams to conduct a System Objective Review and a Preliminary System Specification Review.
- **Phase II:** A 27-month effort by two contractor teams to design and develop the Tier II+ system, complete the definition of the

system specification and all interfaces, produce a prototype system, and successfully complete initial flight testing. The products were to be two prototype air vehicles, one set of sensors, a prototype ground segment, and a support segment capable of demonstrating initial system performance.

- **Phase III:** A 36-month effort by a single contractor team with the primary objective of conducting a successful operational demonstration of the Tier II+ system. The products were to be eight preproduction air vehicle systems fully integrated with all subsystems and sensors (except for two EO/IR sensors); two ground segments capable of supporting the air vehicle segments; and provision of logistics support and planning for a user-conducted two-year field demonstration of the Tier II+ system. This phase would include an irrevocable offer to supply ten air vehicle segments under Lot 1 of Phase IV for the recurring UFP of $10 million in FY 1994 dollars.
- **Phase IV:** An open-ended serial production of air vehicle 11 and subsequent, and ground segment 4 and subsequent.

This program plan, which is used as the baseline, called for Phases I–III to be completed between October 1994 and December 1999 for a total program length of 63 months. Planned annual contractor funding from the Phase I solicitation is shown in Table C.1. Phases II and III were to be executed concurrently for six months in FY 1997.

Total program funding—that is, the above value plus that for government activities—was defined in the initial draft HAE UAV

Table C.1

Tier II+ Program Obligation Plan as of June 1, 1994 (millions of TY dollars)

Phase	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	Total
I	12							12
II		70	110	50				230
III				70	130	50	20	270
Total	12	70	110	120	130	50	20	512

ACTD management plan in December 1994 and is shown in Table C.2. Program content had significantly changed since the June estimate. The changes included recognizing the additional Phase I contractor involvement, the added intention of DarkStar using the Tier II+ ground segment, and the provision of all funding in six rather than seven fiscal years.

Phase I

Tier II+ HAE UAV Phase I experienced 67 percent cost growth in payments to the contractors directly responsible for the system's development. The intention in Phase I was to award three agreements valued at $4 million each. The HAE UAV program office awarded five of these agreements, increasing the total payments to contractors from the planned $12 million to $20 million. This growth occurred not as a result of scope or schedule changes in what was asked of each contractor but as a result of added competition—two additional contractors—directed by the government.

Phase II

Phase II of the Tier II+ program had its funding cut months before the effort began. The originally intended system development contract funding was set at $230 million over 27 months for two contractor teams. In late December 1994, funding was cut to $164 million spent over 32 months for a single contractor team.[1]

Table C.2

Tier II+ Program Funding Plan as of December 15, 1994 (millions of TY dollars)

Phase	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	Total
I	11	32						43
II		62	117	98				277
III				40	142	142	0	324
Total	11	94	117	138	142	142	0	644

[1]Tier II+ Phase II solicitation dated February 15, 1995.

The Global Hawk air vehicle and sensor suite Phase II work began in April 1995. The scope of Phase II was substantially the same as had been envisioned at the beginning of the program. The primary difference was that the planned duration was lengthened to 35 months—April 1995 through February 1998 inclusive.[2] In August 1997, the schedule was extended through the end of 1998, making the effort a total length of 45 months. However, the program office noted that 99 percent of Phase II tasks were completed by June 1998, some six months earlier. Using this date suggests that the phase lasted just 39 months. The amendment formally closing out Phase II is dated September 30, 1999, and was signed off in February 2000. It states the former date as the formal conclusion of the phase, making Phase II 54 months in length. The most appropriate date for Phase II completion appears to be December 31, 1998; thus the phase lasted about 45 months.

The final Phase II cost to the government came to roughly $237.6 million,[3] including some $2.3 million in effort directly contracted for with RayES. The RayES activities were enhancements to the ground segment's capabilities that under the original plan would most likely have been contracted for directly with the Tier II+ prime contractor. The cost of Tier II+ Phase II was 3.3 percent more than the $230 million funding projected in June 1994. If both the planned (FY 1995 through FY 1997) and actual (FY 1995 through FY 1999) expenditure profiles are adjusted to real dollars by adjusting for inflation, the two are essentially equal.

The contractor's products in this phase were close to that envisioned at the time of the Phase I solicitation, but the original plan was to fund two separate contractor teams to deliver these products. This indicates that the cost of the phase's products was twice what was envisioned in the June 1994 program obligation plan.

[2]Some references state that the phase was to be 31 months. This is consistent with the 35-month figure if the August 4, 1995, Agreement amendment sign-off date is considered the beginning of the effort.

[3]As shown in Table B.1.

Phase III

For comparative purposes, the best equivalent to the originally envisioned Tier II+ Phase III is a combination of the following: the actual activities accomplished in Ryan Phase IIB; part of the RayES Phase IIB effort; and all of Ryan's and RayES's Phase III efforts. All RayES efforts would most likely have been subcontracted for by Ryan, the Tier II+ prime contractor, had the original program construct endured. The move away from the original Tier II+ Phase III plan began in April 1995. The phase was then described as an unpriced option to produce and deliver up to eight preproduction air vehicle systems and up to two ground segments. Its duration was shortened from 36 to 30 months. Phase IIB was not envisioned at that time.

Ryan Phase IIB came about in mid-1997, by which time it had become clear that Ryan's Phase II effort would be much more costly and time-consuming than had been envisioned at its inception some two years earlier. Ryan Phase IIB was initiated to avoid a break in production activities at Ryan and to ensure that sufficient flyable assets would be available for the much-shortened operational demonstration to follow. As of August 30, 2000, the final task in the phase was to conclude on September 30, 2000, for a total phase length of 38 months. RayES Phase IIB supplied follow-on ground segments, flight test support thereof, and mission planning enhancements.

The Ryan Phase III effort overlapped with much of Phase IIB. Phase III began in October 1998 with an initial SOW that was finalized in March 1999. The effort did not include the procurement of additional flyable assets. A separate SOW dated January 1999 called for the production of a DTM and added other NRE tasks to the program. This effort, which was initiated by Congress, was adopted in May 1999 and was finalized two months later. These activities, along with Y2K fixes and funding added in May 1999 for studies and analyses, form the content of the Ryan Phase III. Roughly 78 percent of the phase's value was for direct support of flight operations, both D&E exercises and continued engineering development and new air vehicle checkout flights.[4] The remaining resources were dedicated to

[4]All of Ryan CLIN 16 ($67.1 million), all additional expenditures under Ryan CLIN 11 ($4.2 million), expenditures under RayES CLIN 13 ($1.5 million), and all of RayES CLIN 16 ($12.3 million) for a total of $85.1 million. Of the total, some $37 million funded

NRE activities not envisioned for Tier II+ Phase III according to the June 1994 ACTD plan. As of August 2000, the period of performance for Ryan Phase III was through February 2001, for a total length of 27 months. The RayES Phase III effort provided ground segment support and maintenance for the operational demonstration and concluded at the end of June 2000.

The relevant cost figures for the comparison of the actual Ryan and RayES Phases IIB and III to the envisioned Tier II+ Phase III are found in Tables B.3 and B.5. Phases IIB and III had estimated costs of $134.15 and $109.03 million, respectively. As shown in Table C.3, this totals to about $243 million, or 90 percent of the June 1994 planned Tier II+ Phase III budget of $270 million. As of August 2000, the time span in which the two phases were conducted was expected to be August 1997 through February 2001, or 43 months. This is seven months longer than the three-year Phase III program originally envisioned.

In total, and as shown in Table C.3, three air vehicles and one DTM, two ISSs, one CGS, and one additional LRE were built during Ryan and RayES Phases IIB and III. The original plan envisioned eight air vehicles, six complete and two partial ISSs, and two ground segments.

Table C.3

Tier II+ Phase III Hardware Comparison

Hardware Procured	Air Vehicles	Integrated Sensor Suites	Ground Segments	Cost (in millions of dollars)
Actual Ryan and RayES Phase IIB and III	3 plus 1 DTM	2	1 complete; 1 partial	243
Plan for Tier II+ Phase III—June 1994	8	6 complete; 2 partial	2	270

D&E flight operations, and roughly $48 million funded new air vehicle checkout and other developmental flight operations.

Table C.4 employs the following in comparing the actual and planned D&E. D&E flights occurred during nine of the months between June 1999 and June 2000 inclusive. At any one point in time, only one Global Hawk was available for D&E flights. Air vehicle 1 was used from June through October 1999; air vehicle 3 was used in November and December 1999; and air vehicle 4 was used in April and May 2000. Air vehicle 5 flew for the first time on June 30, 2000, after the final operational demonstration had been completed. Except during November and December, only SAR imagery was collected. Useful EO/IR imagery was not collected because the original complete ISS (SAR plus EO/IR) was lost with air vehicle 2 in March 1999; the EO/IR portion of the second ISS was lost shortly after its delivery in the taxi accident of December 1999; and the third ISS was not delivered until after ACTD D&E flights had concluded. The second CGS became available early in the operational demonstration, and the third LRE was delivered shortly before the completion of the operational demonstration.

The original Tier II+ Phase III D&E plan envisioned four air vehicles available for user demonstration at the beginning of the phase, increasing to ten in the final six months of the planned two-year effort. Most of these air vehicles would have had the complete ISS. In the latter half of the effort, the three ground segments envisioned plus eight or more air vehicles would have facilitated up to three simultaneous operational demonstrations—each with multiple aircraft. The original operational demonstration plan circa 1995 called for 2000 flight hours; 381 flight hours were actually accumulated.

Table C.4

Tier II+ Phase III Demonstration and Evaluation Comparison

Duration and Assets	D&E Activity Duration	Participating Air Vehicles	Complete ISS	Partial ISS	Complete Ground Segments	Added LREs
Actual Phases IIB and III	9 months	1 at start; 1 at end	1 for 2 months	1 at start; 1 at end	1 at start; 2 at end	1 at start; 1 at end
Plan for Phase III—June 1994	24 months	4 at start; 10 at end	3 at start; 7 at end	0 at start; 2 at end	1 at start; 3 at end	N/A

Continuing engineering development and air vehicle checkout flights were conducted during Phase IIB, all Phase III D&E, and for a few weeks after the completion of D&E. Another 173 flight hours were flown in for these purposes. This brings the total flight hours during Phases IIB and III to 554.

Table C.5 breaks down the $243 million spent during the Tier II+ program's Phases IIB and III into three categories: hardware procured, added NRE, and flight activity.[5] This breakout facilitates normalization calculations for purposes of content comparison of the originally planned Tier II+ Phase III to the actual combined content of Ryan and RayES Phases IIB and III.

Table C.6 estimates what the cost to the government would have been to execute the original Phase III program. The costs of the actual Phase IIB and Phase III programs as executed were used in this determination. Cost estimates from Table C.1 for the original planned Phase III are shown in the top data row of Table C.6. In the second row, the actual cost of Phases IIB and III from Table C.5 along with estimates of the percentage of the originally planned hardware procured and flight activity are shown. It is estimated that about 40 percent of the originally planned hardware was actually procured and that roughly 25 percent of the originally planned flight activity occurred.

The data in the third row are estimates of the resources that would have been required had additional hardware been procured and flight activity undertaken sufficient to equate that planned for in the original Phase III. The third-row data estimates are based on the actual experience shown in the second row and assume economies of scale. These economies would almost certainly have materialized given the greater volume of activity required in the original plan.

Row 4 simply adds rows 2 and 3 except in the "Total" column, where the NRE of $19 million is excluded—as none was planned for in the original Phase III. Row 5 shows what percentage cost growth would have been expected had the activity content defined in June 1994

[5]The sources of costs are Tables B.3 and B.5.

Table C.5

Tier II+ Cost by Activity for Phases IIB and III (millions of TY dollars)

Actual Phase IIB and Phase III	Hardware Procured	Nonrecurring Engineering	Flight Experience
Ryan CLIN 7: air vehicles 3, 4, and 5	80.9		
Ryan CLIN 10: two complete sensor suites	29.2		
Ryan CLIN 11: air vehicle spares			9.5
Phase IIB award-fee pool	5.1		
RayES CLIN 11: MCE 2 and LREs 2 and 3 (half cost)	8.8		
RayES CLIN 13: CGS spares			2.3
RayES CLIN 15: mission planning upgrades		4.1	
Ryan CLIN 2: studies/analysis		10.0	
Ryan CLIN 16: air vehicle D&E			67.1
Ryan CLIN 17: development test model and NRE	9.1	4.6	
Ryan CLIN 19: Y2K fix		0.2	
RayES CLIN 16: CGS D&E			12.3
Total	133.1	18.9	91.2

Table C.6

Tier II+ Content Normalized for Cost Analysis (millions of TY dollars)

Cost Comparison	Hardware Procured	Nonrecurring Engineering	Flight Experience	Total Cost
June 1994 plan for original Phase III	$170	$0	$100	$270
Actual Ryan and RayES Phases IIB and III	40 percent assets; $133	N/A; $19	25 percent flight hours; $91	$243
Projected additional cost to meet scope of June 1994 plan	60 percent assets; $180	N/A	75% flight hours; $219	$399
Estimated cost for complete scope of June 1994 plan	100 percent assets; $313	N/A	100% flight hours; $310	$623
Estimated cost growth for Tier II+ Phase III	84 percent	N/A	210 percent	130 percent

actually been adhered to. This is calculated by comparing the hypothetical figure in row 4 to that of the original estimate shown in row 1. The estimated cost growth for the hardware portion is calculated to be 84 percent, and that for the operational demonstration is calculated to be 210 percent. As these are very rough estimates, the most precise statements that can be made are as follows:

- Hardware procurement would have cost the government about double that planned had it been completed to the full content scope of the Tier II+ Phase III plan circa June 1994.
- Flight activity would have cost the government about triple that planned had it been completed to the full content scope of the Tier II+ Phase III plan circa June 1994.

In aggregate, it appears that the cost of hardware procured and flight activity in Tier II+ Phases IIB and III was about 130 percent more than what one would have expected given the original program budget.

Phase IV

Phase IV did not occur. The Air Force elected to transition the system into EMD using a "spiral development" approach following the Milestone II decision rather than immediately producing ACTD-configured aircraft.

Complete Tier II+ ACTD

Formal contractor involvement in the Tier II+ ACTD began with Phase I Agreement awards in November 1994. The final flight of the ACTD took place on July 19, 2000, at least symbolically concluding the ACTD. However, CLINs that are part of the ACTD ran through February 2001. This brings the duration of contractor involvement to some 69–76 months. When time before the contractors became involved is included, the activities of the program ran 85 months—

February 1994 through February 2001 inclusive.[6] The ACTD ended between 7 and 14 months later than the December 1999 date originally planned—depending on when one considers the ACTD to have concluded.

The total cost to the government will be about 2 percent less than what was shown in the original program obligation plan circa June 1994. The final cost was constrained by a lack of additional available funding. The activity content of Phase I was unchanged, but additional contractors were included to take advantage of the diverse set of proposed designs. The activity content of Phase II was also essentially unchanged, but just one contractor rather than the originally planned two took part. The activity content of Phases IIB and III was changed and significantly descoped to fit the remaining calendar time and funding in the ACTD.

Table C.7 gives a summary cost analysis for the Tier II+ ACTD program using the original June 1994 program plan as a reference. The "Actual Cost" column gives the figures paid by the government to the contractors over the course of the ACTD. The "Cost of Original Plan" column shows the phase totals from the June 1994 plan. The "Actual Cost Growth" column is simply the percentage difference between the actual and original plan costs.

The "Actual Cost Normalized" column shows the projected cost if the government had purchased all that was planned at the program's

Table C.7

Tier II+ ACTD Cost Analysis (millions of TY dollars)

Equivalent Program Phase	Actual Cost	Cost of Original Plan	Actual Cost Growth	Actual Cost Normalized	Normalized Cost Growth
I	20	12	66.7%	12	0%
II	238	230	3.5%	476	100%
III	243	270	–10.0%	623	130%
Total	501	512	–2.1%	1111	122%

[6]The date that the DARPA/DARO HAE UAV joint program office stood up is used as a proxy for the program's initiation.

outset. In Phase I, the government purchased more than its original plan called for; thus the actual cost normalized is lower than the actual cost. In Phase II, the government purchased only half of its original intent (one contractor team rather than two); thus the actual cost normalized is double the actual cost. In Phase III, which consists of the combined activities of Phases IIB and III in the program as executed, the government purchased only a portion of its originally intended Phase III content, as shown in Table C.6. The rightmost column is simply the actual cost normalized divided by the cost of the original plan minus one—giving the normalized cost growth.

The Tier II+ ACTD program accomplished a different and almost certainly larger set of nonrecurring developmental tasks than had originally been intended. It produced less than half of the air vehicle, sensor suite, and ground segment assets envisioned. It accumulated markedly less total flight experience in both follow-on engineering flights and D&E experience than originally intended.

When normalized for content over the entire ACTD, it appears that the Tier II+ ACTD program's cost grew by somewhere between 100 percent and 150 percent. To avoid an actual cost overrun, both the DARPA and Air Force program offices were willing to radically change what was to be accomplished within the ACTD, with a focus on achieving the objectives of the acquisition strategy rather than blindly following the original ACTD program plan. A favorable MUA was the ultimate goal of the ACTD, and this goal was sought and attained while actual program costs were kept below those in the original plan.

TIER III– PROGRAM

Determining the most appropriate baseline for the Tier III– ACTD program is difficult given that the program lacked clear definition until after its Phase II was under way. Several program or partial program estimates made during the latter half of 1994 were analyzed, and the one that appears most appropriate as a baseline for our purposes was selected. Fortunately, the differences between these early estimates are easily explained and are not great; thus the selection of an alternative baseline would not significantly affect our conclusions.

When the initial Agreement between the HAE UAV program office and LMSW was signed, DARPA and DARO had not completed the process of defining the Tier III– program structure. As a result, the Agreement signed in June 1994, entitled "Tier III– Technology Demonstrator Acquisition Program," simply defined that phase of the Tier III– program. The Agreement called for the design and production of two proof-of-concept flight vehicles, one radar sensor, one EO sensor, data links, and one LCRS. Funding was set between $118 million and $125 million. No specific follow-on activities were described, but the Agreement stated the desire to rapidly and cost-effectively transition into production. The schedule goal for the phase was 21 months, aiming for completion in March 1996.

In July 1994, DARPA and DARO signed an MOU defining a more complete Tier III– program. The content of the Agreement signed with LMSW the month before was designated the baseline program. A follow-on Demonstration Option phase was specified in the MOU.[7] The Demonstration Option phase called for developing two to four additional air vehicle systems. The MOU stated that DARO would be the OSD sponsor and that the agency was to execute the program as an "ACTD/ACTD-like program."

The estimated total cost for all systems, associated support, and field demonstrations for both phases was stated to be approximately $230 million, as shown in Table C.8. Funding was specified by agency and fiscal year but not by program phase. DARPA and DARO each stated that their obligation plan was subject to congressional approval. The combined funding from these two agencies was planned to be $217 million over six fiscal years. The balance of the $230 million total program funding was stated to come from a "classified source."

The program funding profile outlined in the MOU showed a six-year effort. Most FY 1994 through FY 1996 funding was for the Baseline Program. That effort was scheduled to be completed halfway through FY 1996. The remaining program funding, between $105

[7]These phases are referred to as Phase II and Phase IIB, respectively, in other parts of this document.

Table C.8

Tier III– Program Obligation Plan as of July 1994 (millions of TY dollars)

Funding Source	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	Total
DARPA	5	37	25	15	5		87
DARO	37	13	25	30	10	15	130
Classified							13
Total	42	50	50	45	15	15	230

SOURCE: MOU between DARPA and DARO, undated but signed July 11, 1994, and July 26, 1994, respectively.

million and $112 million, was presumably for the Demonstration Option phase in the FY 1996 through FY 1999 time frame. The MOU stated that FY 1996 to FY 1999 funding would be dependent on the following:

- Successful demonstration of military utility;
- Demonstration that the UFP is achievable; and
- Interest by one or more services or agencies in operating the vehicles as part of their reconnaissance infrastructure.

The HAE UAV program was designated an ACTD in October 1994. The HAE UAV joint program office's briefing to JROC that month showed a slightly less ambitious Tier III– program. The Baseline Program, now referred to as Phase II, was shown as ending in March 1996 as per the Agreement with LMSW. Two aircraft and one LRE[8] along with nine months of "limited field demos" were specified in the Demonstration Option phase, which was now referred to as Phase III. This phase was shown to last slightly more than 18 months, stretching into October 1997. The Tier III– program was shown as dormant from October 1997 through the completion of the HAE UAV ACTD in January 2000. After the ACTD, Phase IV, labeled "transition to production," was shown for "one or both" of the HAE UAV aircraft designs.

[8]The chart mistakenly uses the term *LRE*. What must have been meant was *LCRS*, because the LRE was uniquely part of the Global Hawk program until the CGS concept was adopted in early 1996.

The funding briefed to JROC was almost identical to that in the July 1994 MOU. The only differences were that the $13 million from a classified source was not mentioned, and $10 million of FY 1994 funding was shifted to FY 1995. Total funding from the two primary developing agencies, DARPA and DARO, remained $217 million, as shown in Table C.9. The inconsistency of the Demonstration Option phase ending in October 1997, with $30 million of its funding planned in the following two fiscal years, was not explained.

The JROC briefing was the first time that content, cost, and schedule point estimates for the Demonstration Option phase, which became Phase IIB of the DarkStar program, were specified. It was also the earliest point at which the content, cost, and schedule for the Tier III– program's two phases were defined. The defined content is the closest of the early estimates to what actually transpired, and the figures are entirely consistent with those from the July 1994 MOU. Therefore, the figures briefed to JROC are used as the baseline estimate for the Tier III– program, and we refer to the phases of this baseline as the baseline program phase and the Demonstration Option phase. In determining the funding allocation for these two phases, the middle of the range estimate for the baseline program was presumed, with the Demonstration Option phase receiving the balance of the funding.

One additional early program estimate is worthy of mention. In mid-December 1994, the HAE UAV program office released its initial draft

Table C.9

Tier III– Program Obligation Plan as of November 1994 (millions of TY dollars)

Phase	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	Total
Baseline program/Phase II	32	60	29.5				121.5
Demonstration option/ Phase III/Phase IIB			20.5	45	15	15	95.5
Total	32	60	50	45	15	15	217.0

HAE UAV ACTD management plan. This document contained total program funding for both contractor and government efforts as shown in Table C.10. By this time, the type of concept exploration/concept development work done in Phase I of the Tier II+ program was recognized as having been completed in a "prior effort" for Tier III–. This suggests that the $13 million provided by a "classified source" as stated in the July 1994 MOU was for activity prior to the HAE UAV ACTD—and thus that funding would not add to that shown for the Baseline Program and Demonstration Option phases.

In December 1994, the phase under way at LMSW was officially renamed Phase II, and the follow-on phase for additional air vehicle fabrication and field demonstrations was referred to as Phase III. Phase II was now shown to continue through September 1996. Phase III was to begin in October 1996 and continue through December 1999, plugging into the Tier II+ field demonstrations in January 1998. Two air vehicles were envisioned to be built with the funding shown in Phase III, but the draft management plan specified that the ACTD would include the building of up to eight additional aircraft and payloads in that phase pending additional funding.

Baseline Program/Phase II

The Baseline Program, now known as DarkStar Phase II, was contracted for before a baseline estimate for the entire Tier III– program was established. As a result, the content of the phase at its inception is similar to that used as a baseline. The content and cost of the original DarkStar Phase II SOW grew only slightly in the phase's first

Table C.10

Tier III– Program Funding Plan as of December 15, 1994 (millions of TY dollars)

Phase	Prior	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	Total
I	Classified							
II		42	50	68				160
III				5	57	23	23	108
Total		42	50	73	57	23	23	268

17 months. In December 1995, less than four months before the effort was supposed to be complete, significant cost growth and schedule slip were recognized. The crash of the first air vehicle four months later exacerbated the cost growth and schedule slip. The ramifications of the crash were recognized in a July 1996 Agreement amendment. The phase's deliverables were reduced by one aircraft and data link. Making the second aircraft flyable was the primary addition to the SOW. This added an estimated $22 million to the effort.[9]

A number of smaller capabilities and activities not included in the June 1994 SOW, but certainly necessary for accomplishing the objectives of the Baseline Program as understood in late 1994, were added as separate CLINs. Their value in total added about $9 million to the cost of the phase. Cost growth and schedule slip in completing the efforts as outlined in the revised DarkStar Phase II SOW continued through September 1998. In the end, the cost for this effort increased by roughly $38 million. This increase resulted from an underestimation of the efforts required to complete the revised DarkStar Phase II SOW.

Integrating DarkStar ground segment functionality into the CGS added scope that had not been envisioned in the Baseline Program or the DarkStar Phase II SOW agreed to by LMSW in June 1994. This became a major effort by March 1997, ultimately costing about $28 million.

In the end, Phase II ran 54 months, with a cost to the government of $219.8 million. Of the total $98 million cost increase, $70 million was a result of providing what was originally envisioned in the Baseline Program. The remaining $28 million was for activities not part of the original Tier III– program plan—namely the CGS. The $70 million cost growth represents 58 percent more then the original Baseline Program budget. For this amount, the government received one flyable aircraft as intended. For the most part, the remaining objectives and deliverables envisioned for the Baseline Program were provided.

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[9]Derived from a May 16, 1996, letter from DARO Director Major General Kenneth Israel to Representative John Murtha (D-PA). The $22 million excludes $17 million for a replacement air vehicle, effectively air vehicle 5, which ultimately was not priced or built.

Demonstration Option/Phase IIB

The Demonstration Option, referred to in earlier plans as Phase III and evolved into what is now known as DarkStar Phase IIB, was under way at the time of the cancellation of the Tier III– program. This phase began in November 1996, seven months later than its planned beginning date. Had the DarkStar program continued, three air vehicles should have conducted limited flight demonstrations by the spring of 1999. If the limited flight demonstration activity had lasted nine months as intended in the Demonstration Option plan, Phase IIB would have been completed near the end of 1999. Under this assumption, the total length of Phase IIB would have been about 38 months. The November 1994 Tier III– program plan called for the Demonstration Option to last about 18 months.

The activity content of the Demonstration Option as defined in late 1994 and that of Phase IIB at the end of 1998 were similar in the following ways:

- The Demonstration Option called for two aircraft, while Phase IIB called for three. However, the Phase IIB cost reflected just $3 million in long-lead items for the third Phase IIB aircraft. Completion of that aircraft was not priced.
- The Demonstration Option did not specify payloads, but one for each aircraft was implied. Phase IIB called for one SAR payload and one EO payload.
- The Demonstration Option called for one LRE (presumably an LCRS). Our Phase IIB calculations include the cost of updating the CGS to accommodate configuration changes in DarkStar air vehicles 3 and 4 and half of the cost for CGS 2 and LRE 3.
- The Demonstration Option did not specify NRE activity. Phase IIB included multiple NRE studies and items.
- The Demonstration Option specified a nine-month limited flight demonstration. Just prior to DarkStar's cancellation, Phase IIB's cost included $3.65 million for follow-on test and demonstration activity preparation.

Comparing Phase IIB's achievements at the time of program cancellation to the planned activity content of the Demonstration Option

phase provides insight into how much the phase's cost might have grown had it been completed. It appears that the differences between what was planned for the Demonstration Option and what was accomplished in Phase IIB up to its cancellation offset each other to a large degree:

- Phase IIB's air vehicle construction was roughly the same as that planned for the Demonstration Option—the long lead of air vehicle 5 is offset by the fact the air vehicles 3 and 4 had not yet been proven flightworthy.
- Payload acquisitions were substantially the same for the Demonstration Option and Phase IIB.
- System ground segment acquisition for Phase IIB was more extensive than that planned in the Demonstration Option.
- Phase IIB almost certainly included more NRE activity than what was envisioned for the Demonstration Option.
- The Demonstration Option included limited field Demonstrations, which had been planned for but not executed at the time of Phase IIB cancellation.

Unfortunately, a more informed comparative judgment is not possible, as the level of Phase IIB "completeness" at the time of the program's cancellation could not be ascertained. However, it is safe to say that extensive work would have been required to complete Phase IIB. When one compares the planned Demonstration Option activity content to that planned for Phase IIB, it can be seen that the latter was larger in scope. Had Phase IIB been completed, its cost to the government would have been considerably more than the estimated $95.5 million Demonstration Option budget circa November 1994.

The cost of activities perceived to make up Phase IIB was about $104.3 million in the April 2000 final Agreement closeout. This consisted of $85 million in agreed value with LMSW and $19.3 million with RayES. The $104.3 million actually spent on the phase up to its cancellation is only slightly more than the originally planned Demonstration Option funding. It is difficult to estimate what Phase IIB might ultimately have cost at completion, but it appears that it would have been considerably more than what was envisioned for the Demonstration Option.

Complete Tier III– ACTD

The duration of the Tier III– program was some 57 months, from June 1994 through February 1999. Had Phase IIB been completed, the anticipated duration was through at least December 1999, making the length of the program a minimum of 67 months. This is 27 months longer than the duration outlined in the JROC brief of November 1994. The total cost to the government through program closeout was approximately $324.1 million, some 49 percent more than the November 1994 projected funding of $217 million.

Almost all of the cost growth was in the Baseline Program. This was primarily driven by cost growth in the basic effort, including converting the second DarkStar into a flyable test vehicle. The added requirement for commonality with the Global Hawk ground segment was the second largest source of cost growth. The Demonstration Option phase was ultimately funded to about $9 million more than its original planned budget. If the phase had continued, its cost would have continued to grow. The extensive design changes to air vehicles 3 and 4 constituted the primary cause of the continuing cost growth in the phase. These changes required extensive NRE efforts to modify the air vehicle design, which in turn required design changes to the CGS to support the modified air vehicles.

Had the first two phases of the Tier III– ACTD been completed, they would have provided air vehicles, sensor suites, and flight demonstration experience very close to what was envisioned in plans from the latter half of 1994. However, two important outcomes would have been different from what had originally been envisioned:

- The integration of DarkStar ground segment functionality into the CGS was beyond the original intended work scope.
- The basic flightworthiness of the air vehicle design was very much in question at the time of program cancellation; thus, it is difficult to know if air vehicles 3 and 4 could have performed the envisioned field demonstrations.

The cost analysis in Table C.11 follows the format used for the Tier II+ program in Table C.7. Normalization of the Baseline Program simply required removing the effort to integrate DarkStar functionality into the Global Hawk ground segment. The Baseline Program

phase of the Tier III– program experienced actual cost growth of 81 percent. When normalized to original program plans, this cost growth figure declines to 58 percent. The cost through program closeout for the Demonstration Option phase—the equivalent of Phase IIB—is shown, but normalization of costs for this phase was not possible, as this phase was not completed.

Table C.11

Tier III– Phase Cost Analysis (millions of TY dollars)

Equivalent Program Phase	Actual Cost	Cost of Original Plan	Actual Cost Growth	Actual Cost Normalized	Normalized Cost Growth
Baseline Program	219.8	121.5	80.9%	191.9	57.9%
Demonstration Option	104.3	95.5	9.2%	N/A	N/A
Total	324.1	217.0	49.4%	N/A	N/A

Appendix D

COMPLETE ACTD COST AND SCHEDULE

In this appendix we compare the initial ACTD plan to the estimates at completion as of August 30, 2000. This gives us a top-level picture of what the DARPA/DARO program office had in mind in late 1994 and what actually occurred in the ensuing six-plus years, first under DARPA management and then under Air Force management. A short description of the financial outcomes for the participating contractors is included at the end of this appendix.

The first complete program estimate for the HAE UAV ACTD is from the November 8, 1994, HAE UAV joint program office briefing to JROC. The $912 million total and its annual distribution shown in that briefing are the baseline for the program. These same figures are shown in the initial HAE UAV ACTD management plan draft version 1.0 dated December 15, 1994. The funding split between programs is the only difference between the JROC brief and the draft. The Tier II+ total decreased from $695 million to $644 million, and the Tier III– total increased from $217 million to $268 million. The figures from the management plan draft are shown in Table D.1.

The shift in funding was motivated by the program office's decision to select one contractor instead of the previously planned two for Tier II+ Phase II. The HAE UAV program office stated that it was able to both retain competition in the Tier II+ program and inject competition into the Tier III– program by competing the air vehicle development programs against each other. The funding shift facilitated the inclusion of Tier III– in the so-called Phase III fabrication and field demonstration phase. Under the program construct and fund-

Table D.1

HAE UAV ACTD Funding as of December 15, 1994 (millions of TY dollars)

HAE UAV ACTD	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	Total
Tier II+							
Phase I: design	11	32					43
Phase II: develop/system performance test		62	117	98			277
Phase III: fabricate/field demo				40	142	142	324
Tier II+ total	11	94	117	138	142	142	644
Tier III–							
Phase I: classified design studies and efforts							N/A
Phase II: develop/system performance test	42	50	68				160
Phase III: fabricate/field demo			5	57	23	23	108
Tier III– total	42	50	73	57	23	23	268
HAE UAV ACTD total	53	144	190	195	165	165	912

ing split in the December 1994 draft, both programs would field aircraft to be assessed for military utility.

Table D.2 summarizes the December 1994 ACTD funding plan and shows the estimated cost to the government for the ACTD as of August 30, 2000. Because government costs are listed separately in the current estimate but are embedded in the phase figures of the December 1994 plan, only the total for each air vehicle development effort can be directly compared to its original plan. The cost growth shown for the HAE UAV ACTD is approximately 5.6 percent.

The December 1994 plan showed the completion of activity sometime in the fourth quarter of CY 1999. The ACTD completion date is difficult to specify, as D&E flights ended in June 2000; Phase III flights ended in July 2000; the MUA was released in September 2000; and activities associated with Phase III continued through February 2001. Any of these dates could reasonably be considered the completion date for the ACTD. Depending on which are used as beginning and

Table D.2

HAE UAV ACTD Funding (millions of TY dollars)

HAE UAV ACTD	Agreements August 2000	ACTD Total December 1994
Tier II+		
Phase I: design	20	43
Phase II: develop/system performance test	238	277
Phase IIB: Fabricate and develop flight test	134	
Phase III: fabricate/field demo	109	324
Tier II+ total	501	644
Tier III–		
Phase I: design studies and efforts	Classified	Classified
Phase II: develop/system performance test	220	160
Phase IIB: fabricate and develop flight test	104	
Phase III: fabricate/field demo		108
Tier III– total	324	268
Gov't costs, AFOTEC, AFFTC[a]	138[b]	Included above
HAE UAV ACTD total	963	912

[a]AFOTEC = Air Force Operational Test and Evaluation Center; AFFTC = Air Force Flight Test Center.

[b]Derived from the January 22, 1999, HAE UAV joint program office briefing to Jacques Gansler, USD(A&T).

ending dates, the ACTD lasted between 6 and 17 months longer than was called for in its original schedule.

FISCAL OUTCOMES FOR THE CONTRACTORS

The government's original intent was that what it paid to the contractors participating in this program would by and large cover their actual costs—in terms of the value of resources expended—plus a modest profit. What actually happened during the course of the ACTD was quite different. In Phase I of the Tier II+ program, some of the contractors may have spent more than what they were paid. This is customary in early competitive stages of programs with the potential for lucrative future business. For Phase II, both Ryan and the

LMSW/Boeing team eventually agreed to share cost overruns associated with certain activities. Subsequent phases brought modest profits for both prime contractors. The result at the completion of the ACTD was that Ryan forwent much of its profit, and the LMSW/Boeing team spent more of its own funds than the total profit it earned throughout the course of the ACTD. The DarkStar team's losses were substantial. Throughout its involvement in the ACTD, it is believed that RayES earned modest profits from its CGS work.

BIBLIOGRAPHY

"Boeing Condor Raises UAV Performance Levels," *Aviation Week & Space Technology*, April 23, 1990.

Drezner, Jeffrey A., and Robert S. Leonard, *Innovative Development: Global Hawk and DarkStar—Flight Test in the HAE UAV ACTD Program*, MR-1475-AF, Santa Monica: RAND, 2001.

Drezner, Jeffrey A., Geoffrey Sommer, and Robert S. Leonard, *Innovative Management in the DARPA High Altitude Endurance Unmanned Aerial Vehicle Program: Phase II Experience*, MR-1054-DARPA, Santa Monica: RAND, 1999.

Jane's All the World's Aircraft, 1975–1976, Coulsdon, UK: Jane's Information Group Ltd., 1975.

Jane's All the World's Aircraft, 1978–1979, Coulsdon, UK: Jane's Information Group Ltd., 1978.

Jane's All the World's Aircraft, 1989–1990, Coulsdon, UK: Jane's Information Group Ltd., 1989.

Jane's All the World's Aircraft, 1995–1996, Coulsdon, UK: Jane's Information Group Ltd., 1995.

"Secret Flights in 1980s Tested Stealth Recon," *Aviation Week & Space Technology*, May 6, 1996.

Smith, Giles K., Hyman L. Shulman, and Robert S. Leonard, *Application of F-117 Acquisition Strategy to Other Programs in the*

New Acquisition Environment, MR-749-AF, Santa Monica: RAND, 1996.

Sommer, Geoffrey, Giles K. Smith, John L. Birkler, and James R. Chiesa, *The Global Hawk Unmanned Aerial Vehicle Acquisition Process: A Summary of Phase I Experience*, MR-809-DARPA, Santa Monica: RAND, 1997.

"The (Tacit) Blue Whale," *Air Force Magazine*, August 1996.

U.S. General Accounting Office, *Unmanned Aerial Vehicles: Progress Toward Meeting High Altitude Endurance Aircraft Price Goals*, GAO/NSIAD-99-29, December 1998.

"V/STOL Technology Advances Expected," *Aviation Week & Space Technology*, January 31, 1977.

Over the past three decades, efforts to develop unmanned aerial vehicles have been severely hampered by escalating costs, slipped schedules, and disappointing operational results. Recently, however, the Defense Advanced Research Projects Agency, in conjunction with the Defense Airborne Reconnaissance Office, launched an initiative—designated the High-Altitude Endurance Unmanned Aerial Vehicle Advanced Concept Technology Demonstration (HAE UAV ACTD) program—whose objective was to overcome these deficits through the use of a new and innovative acquisition policy. This report evaluates several key elements of this new strategy to determine how they affected the development of two air vehicles: the first a conventional vehicle (Global Hawk) and the second a low-observable configuration (DarkStar). The authors found that the ACTD approach required that the entire development effort be planned at the program's inception, which proved to be a detriment to the effort as a whole. In addition, the program's single requirement—a $10 million unit flyaway price—proved unattainable and was eventually abandoned. At the same time, the authors found that the program's designation as an ACTD, its use of Other Transaction Authority, and its delegation of considerable management responsibility to contractors greatly streamlined the oversight process and lent considerable flexibility to the effort. As a direct result of these factors, the Global Hawk program was judged to have successfully and cost-effectively produced a continuous, all-weather, wide-area surveillance capability for future warfighters. The authors thus conclude that although the DarkStar program was canceled before its capabilities could be fully demonstrated, the HAE UAV ACTD program was in aggregate a success.

ISBN 0-8330-3112-0
52400>
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MR-1474